State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

Comprehensive Review

Suisun Marsh Monitoring Data

1985-1995

Submitted in fulfillment of

The Suisun Marsh Preservation Agreement and

The Suisun Marsh Monitoring Agreement

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Chapter I
Introduction/Overview

Preface
Water. Like so much of California, the history of Suisun Marsh has been shaped by water. This brackish marsh was originally formed by erosion, sedimentation, and the dynamics of a tidal system where fresh river water and saline ocean water meet. In the 1800's, most of the marshlands were diked and converted first to agricultural uses and later to duck clubs. More recently, the politics of water have involved private citizens and governmental agencies in an effort to protect the Suisun Marsh and its wetlands, water quality, wildlife habitats, and recreational values.

This effort has resulted in a number of administrative, legislative, and regulatory actions that affect the marsh and it's uses. This Comprehensive Review document and the monitoring program that it summarizes were required by a number of these actions, primarily the Suisun Marsh Preservation Agreement (SMPA), the Suisun Marsh Monitoring Agreement, and the Suisun Marsh Mitigation Agreement. These three agreements were signed in 1987 by the Department of Water Resources (DWR), Department of Fish and Game (DFG), and US Bureau of Reclamation (USBR). The Suisun Resource Conservation District (SRCD) was also a signatory to the SMPA. These three agreements included provisions for:
- the construction of facilities to deliver lower salinity water to portions of the marsh and meet water quality standards
- a monitoring program to collect data on surface and soil water quality, water elevations, marsh vegetation, and fish and wildlife
- wetlands mitigation for impacts of facilities construction and upstream water diversions
- managed wetland improvements through use of management plans and a cost-share program for installation/improvement of water conveyance facilities for wetland management

The monitoring requirement was described in detail in the Suisun Marsh Monitoring Agreement. Both the Monitoring Agreement and the SMPA required that the data collected by the monitoring program be reviewed every five years.   Since the review was not completed after the first five years, this "Comprehensive Review" will be an assessment of the Agreements, facilities, and monitoring program over an eleven year period (water years 1985-1995) of operation and data collection. Also included is a brief overview of monitoring that has occurred from 1995 to 1999.

To meet the review requirements, this document includes assessments of the data collected and addresses the following questions raised in the Monitoring Agreement:
- Are the objectives of the SMPA being achieved?
- Are the physical facilities operating effectively?

- What are the relationships between channel water salinity, pond water salinity, soil water salinity, and vegetation?
- Are modifications to the Monitoring Agreement needed?

Before describing the monitoring program and the data collected, this Introduction will briefly describe the marsh and factors affecting it, including:

- Hydrology
- Soils
- Management of diked waterfowl habitat
- Studies that have affected habitat management and monitoring
- Legislative and administrative actions
- Physical facilities that DWR has constructed in the marsh.

A. Description of Suisun Marsh

1. Marsh Environment

The Suisun Marsh is located in southern Solano County, California, west of the Sacramento-San Joaquin Delta and north of Suisun Bay (Figure I-1). Due to the combined influences of saline ocean water from Suisun Bay and fresh water from the Sacramento-San Joaquin Delta, Suisun Marsh is a brackish marsh. This intricate land-water area of tidal wetlands, diked seasonal ponds, upland grasslands, and sloughs includes over 10% of the remaining wetlands in California, and is an important part of the San Francisco Bay-Delta Estuary. The Suisun Marsh provides habitats for resident species of plants, fish, and wildlife; spawning and rearing habitats for migratory fish; and wintering and nesting habitats for waterfowl of the Pacific Flyway.

The Suisun Marsh was originally formed by the deposition of silt particles from flood waters of Suisun Slough, Montezuma Slough, and the Sacramento-San Joaquin River network. Prior to diking, the Suisun Marsh consisted of islands separated by a network of tidal sloughs. Portions of these islands were submerged daily by the high tides, while larger tracts of land were submerged during seasonal high tides and winter flood events. The salinity of the water in the sloughs of the marsh varied considerably with season and from year to year. High winter outflows from the Delta and local streams flooded the marsh and provided fresh water in the marsh channels. During periods of low outflow, saline water from the bay gradually replaced the fresh water in marsh channels, resulting in high salinity for periods of up to five months or more each year (DPW 1931a).

The native vegetation of Suisun Marsh consisted of emergent wetland plants such as tules (*Scirpus* sp.), cattails (*Typha* sp.), and rushes (*Juncus* sp.) in the areas of frequent flooding; salt grass (*Distichlis spicata*) on the higher ground not usually flooded; and pickleweed (*Salicornia virginica*) in isolated areas of poor drainage. Salt grass was reportedly the predominant vegetation of most of the marsh. Before any reclamation occurred, the Suisun Marsh was used extensively for pasturing beef and dairy cattle (DPW 1931a).

Levee construction in Suisun Marsh began in the 1860's after the U.S. Congress granted to the states all swamps, marshes, and sloughs, and subsequent State legislation transferred “swamp land” into private ownership to be drained for development. Following the initial construction of low sod levees, and filling of some smaller sloughs with material borrowed from higher ground, salt grass replaced areas of emergent marsh and these areas were more effectively utilized for cattle grazing. Agricultural crops such as beans, asparagus, wine grapes, hay, and grains (Arnold 1996) were raised successfully on some areas of reclaimed land after leaching operations removed salts from the soil. This leaching was done by allowing precipitation to accumulate on the land and then draining it off through flood gates, and by flooding the land with fresh water when it was available from marsh channels (DPW 1931a). In some cases, reclamation of the land required five or six years of such leaching (DPW 1931b). Beginning in the 1920’s, following a series of dry years and increased upstream water storage and diversion, saline water intruded into Suisun Bay more frequently. This led to increasing salinity in the soil, which, coupled with poor drainage and land subsidence, caused failure of most agricultural developments in Suisun Marsh (George et al 1965, Goals Project 1999). Diked areas that were unsuitable for agricultural production were left dry and used for cattle grazing, or were flooded on a seasonal basis and managed as private duck hunting clubs.

From about 1859 to 1879, market hunters were active in the Suisun Marsh, transporting large numbers of birds by boat to the San Francisco bay area. The first private duck clubs were organized around 1880 (Stoner 1937). Because of the large numbers of ducks in the marsh, and its proximity to Bay Area hunters, waterfowl hunting became the primary use of the Suisun marshlands by the early 1930’s (Arnold 1996). Beginning in 1927, the State of California purchased portions of the marsh as State wildlife management areas. These State areas were originally purchased to ease crop depredation by waterfowl in the Central Valley, in addition to providing waterfowl refuge areas and public hunting opportunities (Mall 1969).

In addition to diking and draining of the marshlands, the Suisun Marsh has been modified over the years by natural erosion, upstream hydraulic mining, channel erosion, and changes in Delta outflow (Miller et al 1975).

Today the Suisun Marsh contains approximately 52,000 acres of diked wetlands, 6,300 acres of unmanaged tidal wetlands, 30,000 acres of bays and sloughs, and 27,000 acres of upland grasslands. Most of the diked wetlands are managed for waterfowl hunting; acreage devoted to grazing and agriculture is very small. The Department of Fish and Game manages about 15,000 acres of tidal wetlands, diked wetlands, and upland grasslands.

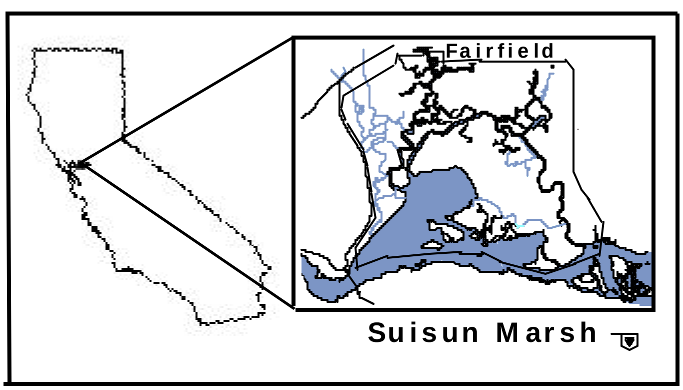


Figure I-1. Map and General Location of Suisun Marsh.

2. Suisun Marsh Soils

Suisun Marsh soils are mixtures of hydrophytic plant remains and mineral sediments. As the marsh formed, plant detritus slowly accumulated, compressing the saturated underlying base material. Mineral sediments were added to the organic material by tidal action and flood events. Generally, mineral deposition decreased with distance from the sloughs and channels (Miller et al 1975). Suisun Marsh soils are termed "hydric" because they formed under natural tidal marsh conditions of almost constant saturation.

All Suisun Marsh soils that were historically inundated by the brackish tides are saline soils. Salts are present throughout the soil profile and maintained there by the saline groundwater and by periodic flooding with brackish channel water. In both channel and soil water there are increasing salinity gradients in the marsh from east to west and from north to south.

The soils adjacent to the sloughs are mineral soils of the Reyes series. These soils have less than 15% organic matter, and although classed as "poorly drained", they are better drained than the more organic soils in the marsh. Tamba soils occur adjacent to the Reyes soils, at a slightly lower elevation, and contain 15 to 30% organic matter. Joice soils occur still farther from the sloughs and contain 30 to 50% organic matter. Suisun soils occur farthest from the sloughs, at the lowest elevations and have over 50% organic matter content. Another common soil in the marsh is the Valdez series, which formed on alluvial fans and contain very low amounts of organic material. Valdez series soils are found primarily on Grizzly Island (Miller et al 1975). The marsh is bordered by upland soils that are non-hydric and contain very little organic material.

Today, large areas of Suisun Marsh are contained within levee systems and are managed as seasonal wetlands. By isolating the soils from daily tidal inundation, the soils have become more saline (DWP 1931b). All Suisun Marsh soils are saline and poorly drained, and each marsh soil presents different challenges to the wetland manager. When allowed to dry, these hydric soils tend to subside, thus lowering the elevation of the pond bottoms. Reyes and Tamba soils become strongly acidic if exposed to air and allowed to dry. The Suisun and Joice soils are difficult to leach effectively, because capillary action and hydrostatic pressure in these organic soils bring saline water upward through the soil profile, making it difficult to maintain low root zone salinity. In addition, Joice soils are prone to cracking when dried.

3. Suisun Marsh Hydrologic Conditions

a. Channel Water Salinity

Factors that affect the salinity in the channels of the Suisun Marsh include, but are not limited to:

- Tides
- Climate: precipitation, wind, evaporation, and barometric pressure
- Delta Outflow
- Suisun Marsh Salinity Control Gate operations
- Creek inflows
- Managed wetland operations
- Urban runoff
- Fairfield-Suisun Treatment Plant effluent inflows

In general, the first five factors have the greatest impacts on channel water salinity, while the last three factors have temporary or localized effects. Water quality monitoring in the marsh has been focused primarily on the salinity effects of Delta outflow, operation of the Suisun Marsh Salinity Control Gates, and creek inflows.

During times of high Delta outflow, the Suisun Marsh has a natural salinity gradient from east to west. The eastern marsh, being closest to the Delta, will have lower channel salinities than the western marsh. When Delta outflow is low, the operation of the Suisun Marsh Salinity Control Gates (discussed further in the Physical Facilities section) lowers the salinity in eastern marsh channels and maintains the east to west gradient.   Without Control Gate operations during times of low Delta outflow, the salinity in the western marsh may be lower than that at some eastern marsh locations. The marsh also has a north-south salinity gradient, with the northern marsh having lower channel salinity during wet months due to local runoff and creek flows.

Salinity in the eastern marsh drops rapidly when Delta outflow increases; however, the southwestern marsh requires high outflow for a longer period of time to achieve a reduction in salinity. Field data and simulation modeling indicate that northwestern marsh salinity is primarily affected by inflows from the watershed to the north and northwest, and by local drainage from managed wetlands.

b. Delta Outflow

The Delta Outflow Index (DOI) is a calculated value defined as the sum of all flows and precipitation runoff minus all agricultural, municipal, and industrial diversions from the Delta. Since the DOI does not reflect daily tidal conditions and is, therefore, an inaccurate estimate of daily net outflow, a more accurate estimate is achieved by using simulation models to incorporate daily tidal fluctuations with the DOI. This measurement is called the Net Delta Outflow Index (NDOI). Both calculations are made over the 24-hour daily cycle (DWR 1995b). Mean monthly NDOI for water years 1985-1995 is graphed in Figure I-2, and total annual NDOI is graphed with annual precipitation at Fairfield in Figure I-3.

Delta outflow is the primary source of fresh water for Suisun Bay and Suisun Marsh. The Department of Water Resources and U.S. Bureau of Reclamation increase DOI with releases from upstream reservoirs and decrease DOI when water is pumped from the Delta for export.

c. Local Creek Inflows

Several creeks originate in the area bordering the Suisun Marsh including Green Valley, Suisun, Dan Wilson, Ledgewood, McCoy, and Denverton. The influence of creek inflows on salinity levels is most significant in the northwestern marsh, where the sloughs are smaller and influences of Delta outflow and Suisun Marsh Salinity Control Gates operation are less pronounced. Suisun and Green Valley creeks are perennial creeks with minimal base flows that respond quickly to precipitation and runoff. The other creeks are ephemeral and usually flow only during times of significant rainfall (DWR 1995a).

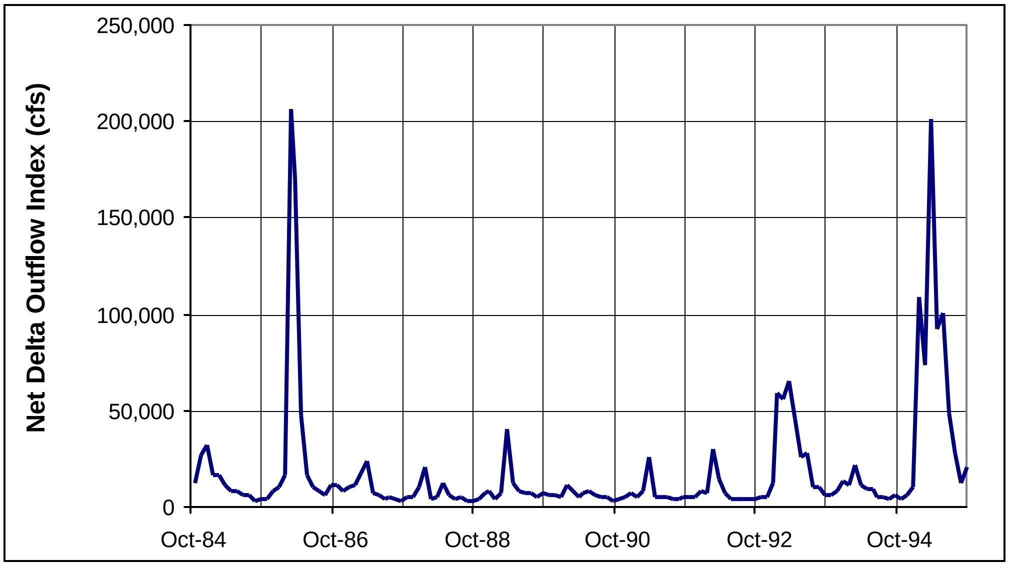


Figure I-2. Monthly Average Net Delta Outflow Index, Water Years* 1985-1995.
*** a water year is from October 1 through September 30 (i.e. WY85 starts Oct. 1, 1984)**

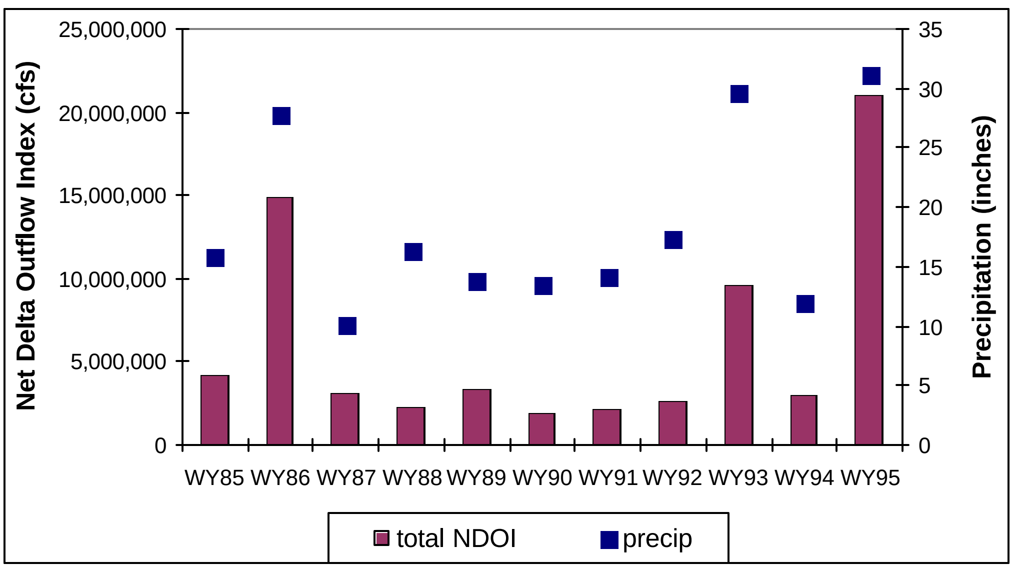


Figure I-3. Total annual Net Delta Outflow Index and precipitation at Fairfield, WY 85-95.

d. Water Year Classifications

The NDOI is used, along with snow surveys and runoff predictions, to calculate and project the water year type on an annual basis (Table I-1). During the monitoring period (1985-1995), water year classifications were defined by Footnote 2 of Table II of Decision 1485 as follows:

"Year classifications shall be determined by the forecast of Sacramento Valley unimpaired runoff (the Sacramento Valley Four River Index) for the current water year as published in California Department of Water Resources Bulletin 120 for the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year."

Water year classifications in order of increasing runoff are: critical, dry, below normal, above normal, and wet. The water year classification affects which salinity standard is to be met in the Suisun Marsh. Of the eleven years from 1985 to 1995, all but three (1986, 1993, and 1995) were classified as dry or critical (Table I-1).

Table I-1. Water Year (WY) type, Water Year Run-Off, Net Delta Outflow Index, and Precipitation at Fairfield Station for WY85 - 95.

	WY85	WY86	WY87	WY88	WY89	WY90	WY91	WY92	WY93	WY94	WY95
WY Type[1]	Dry	Wet	Critical	Critical	Dry	Critical	Critical	Critical	Above Normal	Critical	Wet
WYRO[2] (acre feet in millions)	11.0	25.7	9.1	9.2	15.4	9.2	8.4	8.9	22.4	7.8	33.9
NDOI (total cfs in millions)	4.25	14.9	3.6	2.2	3.3	2.0	2.2	2.6	9.6	3.0	21.1
Precipitation (inches)	15.8	27.8	10.1	16.3	13.8	13.4	14.1	17.4	29.6	11.9	31.2

1\Sacramento Valley Four River Index
2\Sacramento Valley Four Rivers Index Water Year Runoff

e. Precipitation

Precipitation data for Suisun Marsh were collected from the nearest National Weather Service station. The station, referred to as the Fairfield Station, is located just north of the marsh in the city of Fairfield. Annual average precipitation at Fairfield Station for the period 1961-1990 was 21.4 inches (NOAA 1995). Annual precipitation at Fairfield for water years 1985 to 1995 is listed in Table I-1 and monthly values are graphed with annual NDOI in Figure I-3.

B. Historic Strategies for Seasonal Wetland Management

1. Habitat Goals of Managed Wetlands

The fundamental goal of most seasonal wetland management in Suisun Marsh is to provide wintering habitat for waterfowl, and the primary component of that habitat is water. Wetland managers usually begin flooding their ponds with water from adjacent sloughs and channels in early October, and drainage of the ponds begins after the waterfowl season ends in January. Most ponds in the marsh are completely drained by June.

The second important component of waterfowl habitat is vegetation, which provides food, shelter from the elements, and protection from predators. Wetland managers can manipulate the vegetation in their ponds through a variety of management techniques. Burning, discing, and mowing destroys or temporarily removes standing vegetation. Changing the flood duration (the number of days that there is standing water in the pond) affects both the growth of existing vegetation, and the germination of seeds in the soil. Each plant species has a range of tolerance for timing, duration, and depth of inundation.

Plant species also have soil water salinity tolerances, and there are several methods that can be employed to change the salinity of the soil water (a decrease is usually desired by managers in Suisun Marsh). Circulating the water in the pond (an exchange of pond and channel water) acts to flush salts out of the soil. A rapid drain and fill of the pond is called a leach cycle, and this leaching can temporarily lower the salinity of the water in the first foot of soil. This technique is usually used in the spring to create favorable conditions for plant growth and seed-set.

Water and vegetation management are facilitated by effective, well-maintained water control structures such as intakes, drains, and circulation ditches. Rapid, complete drainage is important for salinity control, for if the water is not completely removed from the pond, or if the drainage period is too lengthy, the pond water becomes increasingly saline as it evaporates. The salt remains on the soil surface, contributing to high soil water salinity, and high pond water salinity after flood-up the following October.

Although not an obvious goal of management, the actions of wetland managers arrest the ecological succession that occurs in natural wetlands. Many diked wetlands in the marsh would gradually fill with tules or cattails if managers did not burn, disc, or employ water management actions to prevent this natural succession. Erosion and deposition are dynamic forces that act to change watercourses, elevation, and vegetative character of wetlands, and managers often work to suppress these actions and create more stable environments where they (the managers) are the primary agents of change.

2. Influential Studies of Waterfowl Food Plants and Environmental Effects

Salinity standards set in Decision 1485 and habitat management practices prevalent in the marsh have been strongly influenced by the results of several DFG studies conducted in the 1960s and 1970s.

A waterfowl food habits study which examined the gizzard contents of ducks taken in Suisun Marsh determined that seeds from alkali bulrush (*Scirpus maritimus*), fat hen (*Atriplex triangularus*), and brass buttons (*Cotula coronopifolia*) provided the bulk of the winter waterfowl food supply (George et al 1965).   Many wetland managers, wanting to increase the number of ducks on their ponds, began changing management practices to favor the growth of these three plants.

Later studies (Mall 1969, Rollins 1973) on the habitat conditions necessary for these plants concluded that plant communities in the managed wetlands of Suisun Marsh are controlled primarily by the flood duration and secondarily by the concentration of salts in the root zone (usually the first foot of soil). The optimum flood duration was shown to be 7-8 months for alkali bulrush, and 4-5 months for fat hen. Salt concentration of 11-22 mS/cm in the root zone during May was found to be the most favorable salinity range for alkali bulrush seed production (Mall 1969). These findings were used to establish the Suisun Marsh salinity standards in Decision 1485, which were designed to provide “an average of 90% of maximum alkali bulrush seed production and 60% alkali bulrush seed germination” if efficient marsh management practices were employed (Rollins 1981).

Summaries of these works appear below.

a. An Evaluation of the Suisun Marsh as a Waterfowl Area, Harry A. George et al 1965

The vegetation study used color aerial photography, color interpretations, cover mapping, and planimetry to delineate and measure vegetation types. The results are shown in Table I-2.

There are two limitations to the vegetation survey. The methods used to conduct the field verifications are not given, so it is not known how appropriate they were in light of currently accepted techniques. Secondly, the report states that the vegetation types (Table I-2) were composites of several species dominated by the species for which the type was named, but the composition of the types is not given except for the alkali bulrush type.

Table I-2. Results of 1960 Suisun Marsh vegetation survey (from George et al 1965).

Vegetation type	Acreage	Percent of Cover
Pickleweed	13,546	24.9
Salt grass	12,928	23.7
Annuals	5,862	10.8
Crops	4,379	8
Alkali bulrush	3,333	6.1
Tule	2,929	5.4
Cattail	2,476	4.5
Baltic rush	1,827	3.3
Brass buttons	1,128	2.1
Olneyi bulrush	521	1
Bare ground	262	0.5
Miscellaneous	5,307	9.7
TOTALS	**54,498 acres**	**100 percent**

A soil study was done in conjunction with the vegetative survey. A total of 363 soil samples were collected from the twelve vegetation types identified in the vegetation survey. Soil samples were tested for electrical conductivity and pH. There were several assumptions and conclusions associated with this soil study that may diminish the relevance of the study's results. The report states that "soil salinity is the principal factor limiting the growth of marsh plants in Suisun Marsh". No citation for this assumption was given, and it has not been substantiated by subsequent brackish or salt marsh studies. The researchers concluded that the two highest measurements of soil salinity for each vegetation type were representative of the "approximate level of salt tolerance for the species, beyond which it will not survive". They also concluded that the soil samples collected from areas of bare ground "are beyond the limits of salt tolerance for all species of plants". These two conclusions did not take into account other ecological factors that could affect vegetation in the marsh and provide alternate explanations for the observations made.

The food habits study examined the contents of 1,408 stomachs (gizzards) of pintail, mallard, shoveler, green-winged teal, and wigeon collected in Suisun Marsh during August, September, October and December 1960 and January 1961. Within each species, the frequency of occurrence and volume of each item were tallied as separate percentages. The average volume and average frequency of the five most common plant species found in the gizzards of each duck species are shown in Table I-3a.

This study noted that waterfowl use of alkali bulrush had steadily increased from 8% in 1949 to 37% in 1961, and it was postulated that this increase was due to changes in water management by duck club owners to encourage the growth of alkali bulrush. The report included no data on changes in acreage of alkali bulrush over this period.

This study concluded with a recommendation that landowners begin leaching their properties in the spring, because management that consisted only of flooding for duck season was increasing soil water salinities and was not producing significant amounts of waterfowl food.

b. Soil-water-salt relationships of waterfowl food plants in the Suisun Marsh of California, by Rolf E. Mall, 1969.

Using the gizzard data from George et al (1965), Mall (1969) also analyzed waterfowl food habits, but reported results as Use (Frequency x Volume) and Selection (Use/Relative Abundance of the plant), rather than George's Frequency and Volume. The relative abundance for plant species was calculated from the results of the 1960 plant survey discussed above, and is defined as the percent of ground cover each plant contributed to the total plant cover in the marsh (percent of cover from Table I-2). Mall's results are shown in Table I-3b. Mall points out that the Selection values based upon plant coverage falsely imply that each plant is available to and edible by ducks in proportion to its abundance in the marsh. It is interesting to note the substantial differences in the "top five" species of plants consumed by ducks in the two studies.

Table I-3a. Results of Waterfowl Food Habits Study, 1959-1960 (from George et al 1965).

Northern pintail		Alkali bulrush	Corn	Fat hen	Barley	Pickleweed
	Avg % vol	37	12	8	8	4
	Avg % freq	76	17	33	19	19
Mallard		Alk bulrush	Barley	Corn	Fat hen	Sago
	Avg % vol	30	18	10	9	4
	Avg % freq	71	31	10	36	35
Shoveler		Alk bulrush	Salt grass	Pickleweed	Tule	Sago
	Avg % vol	42	18	11	3	2
	Avg % freq	89	59	48	34	21
Green-winged Teal		Alk bulrush	Brass buttons	Fat hen	Tule	Pickleweed
	Avg % vol	30	16	12	9	5
	Avg % freq	78	41	31	53	27
Wigeon		Pickleweed stem	Pickleweed seed	Grass leafage	Alk bulrush	Brass buttons
	Avg % vol	35	10	7	6	5
	Avg % freq	47	37	12	41	12

Table I-3b. Results of Waterfowl Food Habits Study, 1959-1960 (from Mall 1969).

Northern pintail		Alkali bulrush	Brass buttons	Italian ryegrass	Wiregrass	Barley
	Selection[1]	368	345	238	155	67
	Use[2]	2283	1416	262	46	148
Mallard		Alkali bulrush	Barley	Fat hen	Tule	Dock
	Selection	302	280	80	49	51
	Use	1874	617	296	262	155
Shoveler		Alkali bulrush	Salt grass	Tule	Pickleweed	Brass buttons
	Selection	472	82	39	22	13
	Use	2929	2117	206	403	53
Green-winged Teal		Alkali bulrush	Brass buttons	Fat hen	Tule	Pickleweed
	Selection	375	182	144	89	8
	Use	2323	748	531	471	144
Wigeon		Pickleweed	Wild radish	Beard grass	Brass buttons	Alkali bulrush
	Selection	132	72	47	42	41
	Use	2480	72	80	172	250

1/ Selection = Use/relative abundance of plant in marsh
2/ Use = frequency (of occurrence of plant in sampled gizzards) X volume (of plant in sampled gizzards)

The results of these two food habits studies may have over-emphasized the importance of alkali bulrush seed in the waterfowl diet. It is generally agreed (Swanson and Bartonek 1970, Miller 1987) that studies of gizzard contents alone may not reveal the true nature of the waterfowl diet. Hard, and sometimes indigestible, foods such as seeds can be over-represented in the results, while soft foods such as invertebrates, leaves, and stems are under-represented because the digestive process renders them unidentifiable in the gizzard. Currently (2000) a study of the esophagi of mallards, pintail, and green-winged teal is being done to more accurately determine what these species are eating in the marsh.

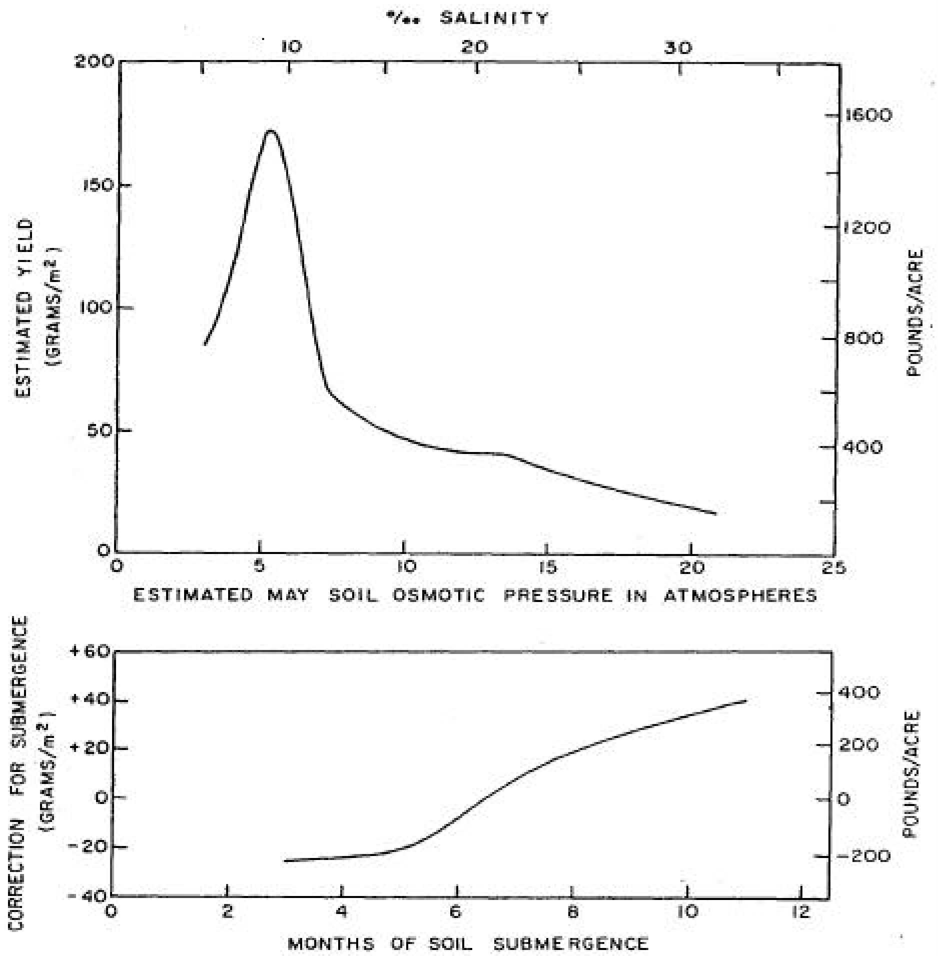
In addition to the food habits study, Mall attempted to determine the effects of soil water salinity, length and depth of soil submergence, soil moisture, salinity of applied water, and soil organic matter on the distribution and growth of marsh plants. These factors and plant growth were monitored at monthly intervals in quadrats within specific vegetative stands, and then end-of-season species composition was related to observed conditions. Mall concluded that the length of soil submergence had the greatest influence on the distribution of Suisun Marsh plants, and within the tolerances for submergence, the concentration of salts in the root zone determined the relative presence or absolute absence of a given plant species. The other variables measured did not appear to contribute any significant control. Mall concluded that spring soil salinity controlled the amount of alkali bulrush seed produced, and seed production was maximized at May soil water salinity levels of 7-14 ppt. This result was used in establishing the water quality standards in D-1485.

Mall's studies of the salinity tolerance of alkali bulrush did not include controlled experiments to determine the specific factors contributing to the results. Physical and biological factors such as waterlogging, soil chemistry, nutrient availability, competition with other plant species, and interactions with animal species, were not measured and may have influenced the results. The observations made by Mall were from a limited number of sites, and were not replicated. Mall did not control the various factors that affect salinity tolerance or seed production, and his conclusions do not explain the results. Because these were the only salinity studies from Suisun Marsh, they were used to determine the D-1485 salinity standards for the marsh, but their accuracy is in question.

Mall conducted his studies of plant salinity tolerances over just two years. Results of the DWR on-site monitoring program indicate that conditions change from year to year, and that two years of data may be inadequate for drawing definitive conclusions about relationships between vegetation and environmental conditions. Mall pointed out that "most of the plants investigated were perennials and the current status and growth of such plants could have resulted from prior conditions that were different from those measured during this study". A two-year study is probably inadequate to determine seed production, channel water salinity levels needed to maximize seed production, or to quantify "maximum seed production". However, Mall did observe important relationships between above ground growth patterns, flooding depth, and channel salinity, but these are probably applicable only at the actual study sites.

The graphs in Figure I-4a are from Mall (1969) and estimate a specific relationship between May soil water salinity, flood duration, and alkali bulrush seed production (on plots dominated by alkali bulrush). The data collected by the on-site monitoring program did not substantiate Mall's estimation. Mall used a multiple regression analysis to generate Figure 1-4a, but because the independent and dependent variables were not known, it was impossible to replicate his regression analysis. Without multiple regression the data collected by the on-site monitoring program show no correlation between flood duration, May soil water salinity, and alkali bulrush seed production (Figure 1-4b). These graphs reveal only that seed production drops off when May soil water salinity exceeds 30 mS/cm (19 ppt) and when flood duration exceeds 250 days.

Finally, the salinity standards developed from this study were established to achieve levels of alkali bulrush seed production that are probably not sustainable year after year. This perennial plant reproduces via both rhizomatous growth and seeds, and does not usually produce large amounts of seed every year (P. Adams 1990).



from Mall (1969).

Figure I-4a. Multivariate analysis relationship between alkali bulrush seed production and soil water salinity and flood duration.

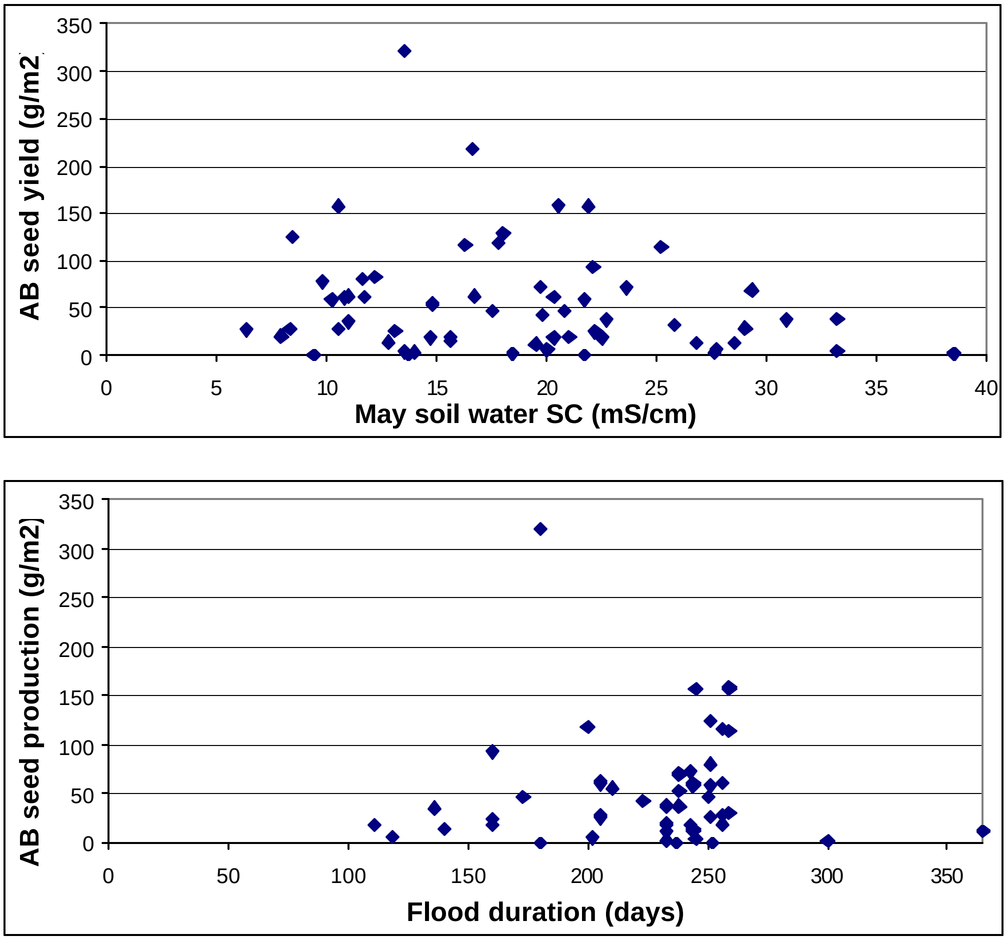


Figure I-4b. Alkali bulrush seed production related to May soil water SC and flood duration. Raw data from Suisun Marsh monitoring program, WY85-95.

c. Relationships Between Soil Salinity and the Salinity of Applied Water in the Suisun Marsh of California, 1973, by Glenn L. Rollins

This study by Rollins investigated the effects of applied water salinity on soil water salinity. Part 1 of the study measured soil water salinity on four duck clubs in the western marsh. Parts 2 and 3 were conducted on a small study pond where infiltrometers were used to apply water of known salinity to small plots. Part 2 was an “accelerated” study where salinity measurements over a few weeks were used to substitute for salinity measurements made over as many months. The experiments in Part 2 did not result in the high soil water salinities observed under natural conditions, so Part 3 used the same equipment and procedures as Part 2, but measurements were taken in real time.

The results of the duck club study (Part 1) showed that soil type influenced percolation, drainage, and soil water salinity; water delivery ditches aided in speeding drainage and removing salts from the soil; flooding with low salinity water reduced soil water salinity;

and when ponds were flooded only for waterfowl season, resultant soil salinity was too high to promote the growth of preferred waterfowl food plants.

From the results of the infiltrometer study (Parts 2 and 3), Rollins concluded that there was a statistically significant relationship between applied water salinity and the soil water salinity. In the graphs used to illustrate this relationship, salinity is charted as soil salt concentration, but much of the text refers to soil salt amount. Salt amount and concentration are not strictly comparable; the latter is dependent upon soil moisture.

One of Rollins' key results is the effect of leaching with low salinity water, which reduced soil water salinity. Rollins qualified this finding however, by noting that his study pond was much smaller than any actual duck club pond and drainage was relatively efficient, and that water managers could not expect to see such dramatic results on their own ponds. Rollins recommended that a combination of improved management practices (including a spring leach cycle), improved drainage and control facilities, and a supplemental supply of fresh water were needed to attain desired soil conditions for waterfowl food plants.

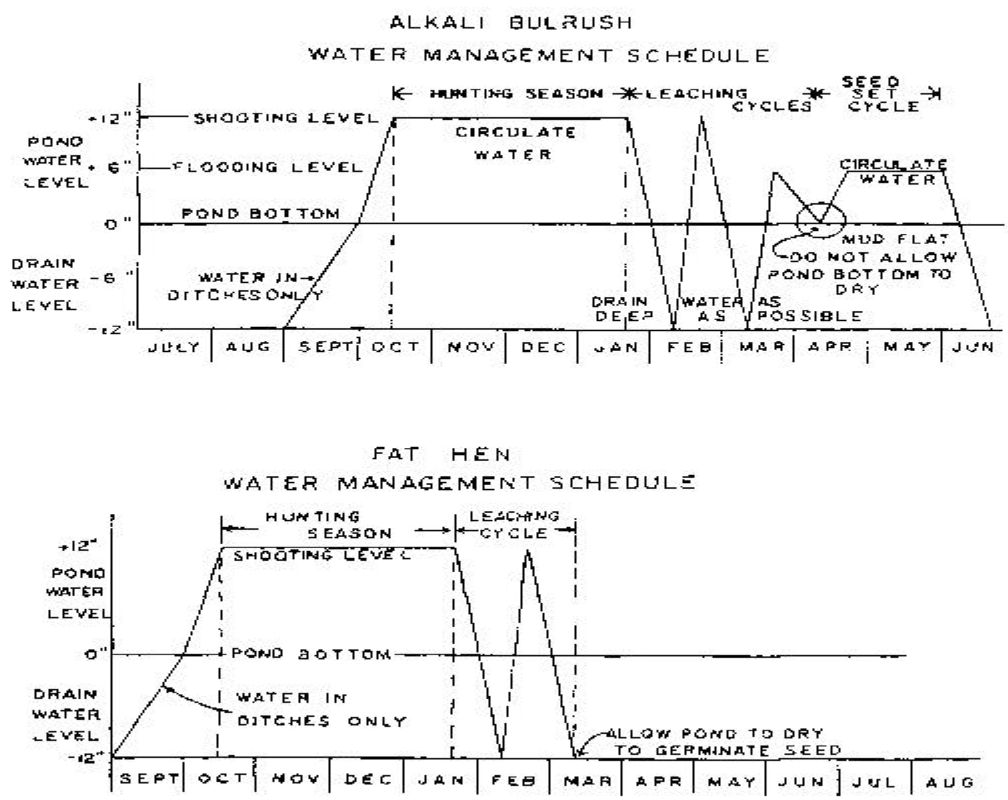
3. Development of Early and Late Drawdown Management Plans

The research conducted by Mall (1969) and Rollins (1973) on the salinity tolerance of the plants identified by George et al (1965) as waterfowl food plants was used to establish the water quality standards in Decision 1485. Rollins used these research results to develop maximum applied water salinities that were estimated to provide an average of 90 percent of maximum alkali bulrush seed production and a 60 percent seed germination rate. The DFG used these estimates as guidelines for long-term management and maintenance of wetlands in Suisun Marsh. Rollins (1981) reported that these guidelines represented the most saline water that could be regularly applied to well-managed seasonal wetlands without loss of alkali bulrush seed production. According to these guidelines, wetland managers, when provided with water within the applied water salinity guidelines and adhering to the late drawdown management schedule (see below), should attain the soil water salinities in Table I-4 (Rollins 1981).

These findings were also used to establish management regimes to enable wetland mangers to grow large stands of alkali bulrush or fat hen. The late drawdown water management schedule (Figure I-5, top) produces dominant stands of alkali bulrush and subdominant stands of fat hen and brass buttons while retarding the growth of plants such as tules, cattails, saltgrass, and pickleweed. The late drawdown schedule calls for the ponds to be leached twice after hunting season, then reflooded to one-half shooting depth (shooting depth is 8-12 inches), drained just to mudflat, reflooded to one-half shooting depth and circulated in April and May to facilitate the seed-set cycle of alkali bulrush. Final drain occurs in early June, following circulation and seed-set (Rollins 1981).

Table I-4. Department of Fish and Game salinity guidelines for optimal alkali bulrush seed production. SC=specific conductance.

Month	Applied Water SC (mS/cm)	Soil Water SC (mS/cm)
October	18.8	50.0
November	15.6	37.5
December	15.6	31.2
January	12.5	25.0
February	7.8	15.6
March	7.8	14.1
April	10.9	14.1
May	10.9	11-22



from Rollins (1981)

Figure I-5. Two common water management regimes employed in Suisun Marsh. The top figure, Late Drawdown Management, results in the growth of alkali bulrush (*Scirpus maritimus*). The bottom figure, Early Drawdown Management, provides conditions favorable to fat hen (*Atriplex triangularus*).

The early drawdown water management schedule (Figure I-5, bottom) was developed to produce stands of fat hen and brass buttons, while suppressing plants such as tules, cattails, and saltgrass. Fat hen management is only recommended for relatively level areas with well-drained soils and efficient water control facilities, because without these conditions soil salinity may increase, creating conditions favorable to pickleweed. An early drawdown schedule requires that ponds be leached once to a depth of at least one foot below pond bottom following the end of hunting season. Subsequently, the ponds are flooded to shooting depth and drained completely by mid-March. Fat hen seedlings will only become established after the removal of surface water (Rollins 1981).

In the 1970s, using primarily the water management schedules outlined above, the Suisun Resource Conservation District prepared water management plans for each of the privately managed wetlands in the marsh. In recommending water management schedules and improvements in both water and vegetation management, these plans took into account each ownership's mean pond bottom elevation, external (slough) tide elevation range, water control facilities, soils, and habitat goals. In the mid 1980s the District recommended that the clubs periodically change their water management regimes to discourage the production of monocultures and increase diversity of wetland plants. The DFG prepared its own management plans for State-owned land in the marsh; these also relied heavily on the early and late drawdown schedules.

4. Management Regimes Practiced by Landowners During the Monitoring Program

Most wetland managers in the Suisun Marsh begin flooding their ponds on October 1 in preparation for the fall migration of waterfowl. To reduce mosquito production in the marsh, Solano County Mosquito Abatement District does not recommend flooding before October 1, unless the landowner can flood and drain the wetlands within 10 days or is willing to pay for mosquito control spraying.

When possible, wetland managers use gravity flow to fill and drain their ponds. Consequently, the ponds are filled during high tide when the water can flow through inlet gates into the pond. Unfortunately, this means that the ponds are flooded when applied water salinity is at its highest. The ponds are drained through drain gates during low tide when water elevation in the ponds is higher than that of the adjacent slough.

During initial flood-up in October, the inlet gates are opened and the drain gates remain closed to allow the ponds to fill to a depth of about 8-12 inches. After initial flood-up, water is diverted from adjacent sloughs, circulated and then drained while maintaining water at the 8-12 inch depth. Compared to the initial flood-up period, relatively small amounts of water are exchanged between the sloughs and the ponds during circulation. The circulation of water maintains water quality in the ponds and helps to prevent stagnant areas from developing. Circulation also helps prevent an increase in pond water salinity resulting from evaporation, and helps to maintain natural soil water salinity. Typically, the ponds are dewatered in late January to begin leaching cycles and other management activities.

Production of a diverse assemblage of wetland vegetation requires managers to base their management on factors such as soil water salinity, depth and duration of soil submergence, and applied water salinity. Appropriate management, including circulation and leaching, is required to prevent increases in soil water salinity above natural levels for Suisun marsh soils (USDA 1977). Leaching usually begins in February and can take from one to four months, depending on the water management schedule being implemented. Final drainage of the ponds occurs between March and June to allow vegetative growth and to perform necessary maintenance activities during the summer.

NMFS and USFWS have imposed water diversion restrictions on unscreened diversions in the marsh to avoid adverse impacts to delta smelt, winter-run Chinook salmon, and other resident and anadromous fish populations. Therefore, implementing these water management schedules often cannot be achieved. Effective maintenance of soil salinities may not occur on properties with the diversion restrictions in place, unless a fish screen has been installed. By 1998, the SRCD Diversion Screening program had installed twelve screens on private intakes.

During the course of this monitoring program (1985-1995), many different water management schemes were practiced by the landowners in the marsh. Of the ponds included in the monitoring program, different water management regimes were usually applied each year of the monitoring program. The most common scheme was for the ponds to be flooded for waterfowl season and then drained between March and June with no leach cycles (flood duration between 150 and 250 days). Landowners' attempts to adhere to either the early or late drawdown regime as outlined by Rollins (1981), met with varying degrees of success. Despite Rollins' (1981) recommendation to use leach cycles to decrease soil water salinity, only half of the ponds in the monitoring program regularly (at least 40% of the time) used this practice.

5. Problems Associated with Management of Diked Wetlands

In tidal wetlands, the soil is always moist and the presence of water in the soil and the flushing action of the tides keep the salt concentration at fairly constant levels. The building of dikes isolated the marshlands from daily tidal action and the leaching effects of winter fresh water flooding. Management of these diked ponds for waterfowl habitat has typically included initial flood up in the fall (when the water in marsh channels is often near its annual maximum), drainage after the end of waterfowl season, and leaving the ponds dry through the summer. These months of dry conditions cause the salinity of the soil water to increase as water is lost through evaporation and saline water is drawn up from lower areas of the soil profile. Soil water salinity decreases when the ponds are flooded again in the fall, but over time salts can build up in the soil profile, causing an increasing trend in salinity. Soil water salinity can increase to concentrations that are toxic to plants, leaving salt-scalded bare ground. Drying the ponds during the summer months also leads to other adverse changes in the soil, including: soil shrinkage and cracking, collapse of clay lenses (Miller et al 1975), and acidification of the soil from the formation of sulfuric acids and sulfates in the soil. Some ponds in the marsh are subsiding because the levees prevent deposition of silt, and discing or burning of vegetation can retard peat formation.

The largest concern of Suisun Marsh landowners is high soil water salinity, which can be exacerbated by management actions. Many studies in the Suisun Marsh have stated that when brackish or saline wetlands are diked, flooded with saline water, and kept dry for part of the year, the result is increased soil water salinity (DPW 1931a, George et al 1965, Mall 1969). These studies have advised managers to circulate water in the ponds and to leach in the spring with low salinity water to decrease soil salts.

In addition, landowners in the marsh have tried to create conditions favorable to plant species (alkali bulrush, fat hen, brass buttons) which were not historically abundant in the marsh, and to minimize the two historically most common species, salt grass and pickleweed. George (1965), in a discussion of water management practices, stated that "pickleweed and salt grass dominate those area where poor water manipulation is practiced, whereas most of the stands of alkali bulrush occur where the water is manipulated to its advantage". It is important to note that despite large scale water projects and diversions, and less-than-ideal water management in the marsh, the managed wetlands of the marsh have remained productive and vegetatively diverse.

C. Legislative and Administrative Actions

1.   History of Legislative and Administrative Actions Affecting the Suisun Marsh.

a. Formation of Suisun Resource Conservation District

In 1963 the SRCD was formed by private landowners in the Suisun Marsh. SRCD was developed to perform administrative, regulatory and technical functions that include: representing landowner interests, both individually and collectively; obtaining environmental permits for routine maintenance activities; preparing wetland management plans for all private lands within the district; and providing technical expertise on issues related to marsh management. The district includes 52,000 acres of managed wetlands, 6,300 acres of unmanaged tidal wetlands, 30,000 acres of bays and sloughs, and 27,700 acres of upland grasslands. There are 158 privately owned duck clubs in the marsh, and the DFG manages about 15,000 acres of the managed and tidal wetlands.

b. 1970 Memorandum of Agreement

On July 13, 1970, a memorandum of agreement was signed by the USBR, the U.S. Fish and Wildlife Service (USFWS), DWR, and DFG. One of the goals of this agreement was to select a water supply and marsh management plan that would protect and enhance waterfowl habitat in Suisun Marsh (USFWS 1981).

c. 1974 Suisun Marsh Preservation Act

The California Legislature, recognizing the threat of urbanization to Suisun Marsh, enacted the Nejedly-Bagley-Z'berg Suisun Marsh Preservation Act of 1974 (SB 1981). The act required the DFG and the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan to protect the marsh. In December 1975, the Department of Fish and Game released the Fish and Wildlife Element of the Suisun Marsh Protection Plan (Jones and Stokes 1975), which contains an inventory of fish and wildlife species found in and around the marsh, an interpretation of how the marsh functions, and recommendations for protection of the marsh.

d. 1976 Suisun Marsh Plan of Protection

In 1976 the BCDC submitted the Suisun Marsh Protection Plan to the California Governor and Legislature (DWR 1984). The Protection Plan divided the marsh into primary and secondary management zones based on land use. Tidal wetlands and diked lands managed as wetlands were placed in the primary management zone; uplands and lands adjacent to the marsh were classified as the secondary management zone. The purpose of the secondary management zone is to provide a buffer between urban development and wetland areas of the marsh. Under the Suisun Marsh Protection Plan, the BCDC serves as the permitting agency for all major projects within the primary management zone and as an appellate body with limited functions in the secondary management area. The Suisun Marsh Protection Plan recommended that local agencies develop a plan of compliance, recommended and prioritized the acquisition of properties, proposed a tax assessment plan based on land use, and identified both State and federal sources of funding to achieve its objectives.

e. 1977 Assembly Bill 1717

In 1977, the California Legislature passed Assembly Bill 1717, which added the Suisun Marsh Preservation Act of 1974 to the Public Resources Code and implemented the recommended protection measures outlined in the Suisun Marsh Protection Plan. This act emphasized the importance of the marsh as a unique and irreplaceable resource, particularly because of the habitat available for wintering waterfowl.

f. 1978 Water Right Decision 1485

In August 1978, the State Water Resources Control Board (SWRCB) adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh (SWRCB 1978a). At the same time, the SWRCB issued Water Right Decision 1485 (D-1485), which implemented the standards in the Water Quality Control Plan (SWRCB 1978b). D-1485 set channel water salinity standards for Suisun Marsh from October through May to preserve the area as a brackish water tidal marsh and to provide optimum waterfowl food plant production. Channel water salinity standards were set for the following Suisun Marsh monitoring stations (Figure I-6):

- Chipps Island at O&A Ferry Landing
- Collinsville on Sacramento River (C2)
- Miens Landing on Montezuma Slough (S64)
- Montezuma Slough at Cutoff Slough (S48)
- Suisun Slough near Volanti Slough (S42)
- Suisun Slough near mouth (S31)
- Goodyear Slough south of Pierce Harbor (S35)
- Cordelia Slough above Southern Pacific railroad (S32)

D-1485 also placed operational conditions on water right permits for the Central Valley Project (CVP) and State Water Project (SWP). Order 7(a) of D-1485 required the permittees to develop and fully implement a plan, in cooperation with other agencies, to ensure that the salinity standards are met.

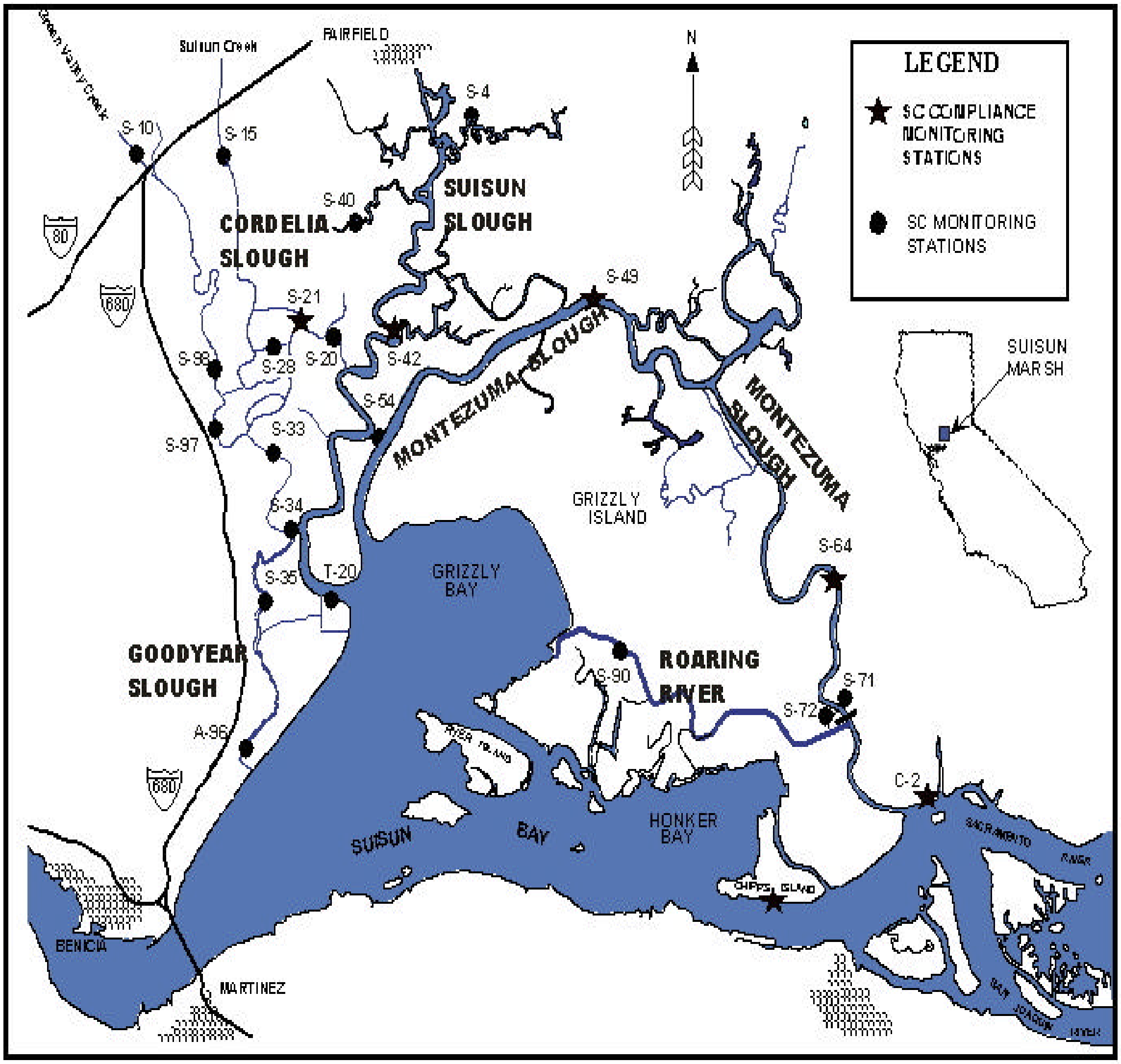


Figure I-6. Channel water SC monitoring stations in Suisun Marsh, active between water years 1985 and 1995. Stations set up to primarily monitor drain water from managed wetlands are shown in Figure I-8.

In D-1485 Order 7(b), SWRCB directed USBR and DWR to develop and implement a plan by October 1, 1984, to protect the marsh. In February 1984, DWR submitted the Plan of Protection for the Suisun Marsh, but was not able to implement the plan by the 1984 deadline. In the meantime, DWR and USBR provided partial mitigation through Initial Facilities constructed pursuant to Order 7(c) of D-1485 and through the December 1978 contract (discussed below) among SRCD, DFG, and DWR.

g. 1978 Agreement for the Initial Facilities

In December 1978, DWR, DFG, and SRCD signed an agreement defining responsibility for construction, operation, and maintenance of the Initial Facilities. The purpose of the Initial Facilities[1] was to partially restore and maintain the marsh as a brackish water marsh capable of producing high-quality food and habitat conditions for waterfowl and other marsh wildlife. The Initial Facilities were intended to partially mitigate the adverse effects on the marsh of operations of the SWP and CVP, which diverted historic Delta outflow to water users south of the Delta.

One purpose of the Agreement was to partially define the responsibilities of DWR to mitigate for the effects of increased salinity levels of water available to certain managed wetlands in the Suisun Marsh. The agreement states, among other things, that DWR shall design, construct, operate, and maintain the Initial Facilities solely at its expense (or in cooperation with USBR) and in compliance with applicable laws.

h. 1984 Plan of Protection for Suisun Marsh

In 1984, DWR published the Plan of Protection for Suisun Marsh including Environmental Impact Report, prepared in cooperation with DFG, SRCD, and USBR in response to D-1485, Order 7. The USFWS also provided significant input. The Plan of Protection was a proposal for staged implementation of a combination of activities including monitoring, a wetlands management program for marsh landowners, physical facilities, and supplemental releases of water from CVP and SWP reservoirs. With staged implementation, each action would be evaluated to determine the need for subsequent actions.

The Initial Facilities and the Suisun Marsh Salinity Control Gates have been constructed and are being operated. Planning and environmental documentation for additional facilities in the western marsh, (Phases III and IV) were also conducted from 1990-1995. However, the signatories to the SMPA (DWR, DFG, USBR, SRCD) agreed that the additional large-scale facilities described in the Plan of Protection and the Suisun Marsh Preservation Agreement (or equivalent actions) are no longer necessary for salinity control in Suisun Marsh because of the effective operation of the Suisun Marsh Salinity Control Gates and the increased outflows provided under the 1994 Principles of Agreement and the 1995 Water Quality Control Plan (described below). Instead, the parties are developing an Amendment to the SMPA (discussed below).

i. 1985 Amendment to D-1485

In 1985, the SWRCB modified Table II of D-1485 to extend the effective dates and location criteria of the channel water standards. The revised effective dates for the standards became, beginning October 1 of each specified year:

- 1988 at monitoring stations C2, S64, S49 (Figure I-6).
- 1991 at monitoring stations S21 and S33 or 1993 at S21 and S97[1].

[1] Initial Facilities consist of Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall (Figure I-6).

- 1991 at monitoring station S35 or 1994 at station S75[2].
- 1997 at monitoring station S42.

The 1985 implementation schedule recognized the planned phased construction described in DWR's 1984 Plan of Protection for the Suisun Marsh, (discussed below).

j. 1987 Suisun Marsh Preservation Agreement

On March 2, 1987, DWR, DFG, USBR, and SRCD signed the Suisun Marsh Preservation Agreement (SMPA) to mitigate for impacts on marsh salinity from the CVP, SWP and other upstream diversions. The objectives of the SMPA are:

- To assure that USBR and DWR maintain a water supply of adequate quantity and quality for managed wetlands within the marsh. This is to mitigate adverse effects on these wetlands from operation of the CVP and SWP and a portion of the adverse effects of other upstream diversions.

- To improve marsh wildlife habitat on these managed wetlands.

- To define the obligations of USBR and DWR necessary to assure the water supply, distribution, management facilities, and actions necessary to accomplish these objectives.

- To recognize that water users in the marsh (i.e., existing landowners) divert water for wildlife habitat management within the marsh.

To meet these objectives, the original SMPA established channel water salinity standards similar to those in D-1485 and a schedule for construction of large-scale facilities in Suisun Marsh that would enable the salinity standards to be met. USBR and DWR had responsibility for funding and constructing the facilities and for meeting the salinity standards. Construction of the facilities was to be in phases, based on evaluation of need and effectiveness of the facility previously constructed. From 1980 to 1993, a number of facilities were constructed in the marsh, and these are discussed below. In 1990, the DWR and USBR agencies began planning the Western Suisun Marsh Salinity Control Project, the objective of which was to develop facilities or activities in the western marsh that would compensate for the higher channel salinities in that area of the marsh, and was designed to fulfill Phases III and IV of the Plan of Protection.

DWR and USBR stopped work on planning and environmental documentation for the Western Suisun Marsh Salinity Control Project in April 1995 because of the increased outflows predicted from implementation of the 1994 Water Quality Control Plan and the effective operation of the Suisun Marsh Salinity Control Gates.

1 DWR and USBR elected for S21 and S97.

2 DWR and USBR elected for S-75, but in 1994 they requested to move the location to S-35 due to problems with establishing the S-75 location.

k. 1987 Suisun Marsh Monitoring Agreement and Mitigation Agreement

DWR, USBR, and DFG signed two companion agreements on March 2, 1987, the Suisun Marsh Mitigation Agreement and the Suisun Marsh Monitoring Agreement (DWR et al 1987a, DWR et al 1987b). The Mitigation Agreement requires acquisition, development, operation, and maintenance of mitigation lands to offset loss and degradation of wildlife habitat resulting from construction of SMPA facilities and impacts of the CVP, SWP, and other upstream diverters on the channel islands. The Monitoring Agreement requires implementation of the monitoring program described under the Plan of Protection for Suisun Marsh. The SMPA references the Mitigation Agreement and Monitoring Agreement and incorporates their requirements.

l. 1991 Water Quality Control Plan

In May 1991 the SWRCB adopted the 1991 Water Quality Control Plan for Salinity, which set new objectives for salinity, dissolved oxygen, and temperature for protection of fisheries-related and agricultural supply beneficial uses. The plan did not include flow and operation requirements needed to improve protection of fisheries-related beneficial uses. Therefore, in September 1991 the U.S. Environmental Protection Agency (USEPA) disapproved parts of the plan, believing it did not provide adequate protection for the estuarine habitat and other designated fish and wildlife uses of the Bay-Delta Estuary. The disapproved objectives remained in effect until January 1994, when the USEPA published draft standards for protection of fisheries-related beneficial uses in the Bay-Delta Estuary.

m. 1994 Principles for Agreement on Bay-Delta Standards

In December 1994, State and federal agencies signed the Bay-Delta Accord, also called the Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government. Participating agencies included the U.S. Environmental Protection Agency, the National Marine Fisheries Service, The Bureau of Reclamation, the U.S. Fish and Wildlife Service, the California Resources Agency, the Department of Water Resources, the Department of Fish and Game, the California Environmental Protection Agency, and the State Water Resources Control Board. The Accord consisted of four components: 1) establishment of the CALFED Bay-Delta Program dedicated to developing a long-term ecosystem approach to solving issues in the Delta; 2) establishment of the Ops Group, a decision making group within CALFED; 3) a commitment by the water user community to fund $10 million annually for three years for non-flow related ecosystem restoration activities to improve the health of the Bay-Delta ecosystem; and 4) final USEPA water quality standards for the Bay-Delta, as well as interim State standards proposed by the SWRCB. The standards consisted of four parts: 1) salinity criteria in Suisun Bay; 2) survival targets for young migrating Chinook salmon; 3) salinity criteria to protect fish spawning grounds on the lower San Joaquin River; and 4) narrative criteria for the Suisun Marsh tidal wetlands.

n. 1995 Decision to Amend the Suisun Marsh Preservation Agreement

In July 1995, a DFG, DWR, USBR, and SRCD Negotiation Team convened to begin updating the SMPA, pursuant to Articles 4,8(h), and 17 of the original SMPA. This decision was based on changed conditions resulting from effective operation of the

Suisun Marsh Salinity Control Gates and increased Delta outflows under the 1995 Water Quality Control Plan. The proposed SMPA Amendment Three is the outcome of these negotiations.

The SMPA was previously amended on two occasions. The first amendment was signed in 1988 and resulted in changes in the S-21 monitoring station location, and in the construction schedule for the Cygnus and Lower Joice Island facilities. The second amendment was signed in 1994 and resulted in an increase in the Individual Ownership Cost Share Program (Article 7) from a 50 percent to a 75 percent cost-share reimbursement by DWR and USBR to the landowners.

Based on analysis of several years of hydrodynamic and salinity modeling and water quality data collected in the Suisun Marsh, DWR and USBR concluded that SWP/CVP operations and other diversions upstream of Chipps Island have not significantly affected flow or water quality patterns in creeks north and west of Suisun Marsh (DWR 1994). However, urbanization and land development north and west of the marsh do significantly affect the pattern of creek inflow, sediment, and water quality entering the marsh. Also, data collected from private and public managed wetlands indicate that water management plays a pivotal role in achieving soil water salinity and habitat goals (DWR Annual Reports 1992-1994). In addition, a prolonged drought, such as the one in 1987 through 1992, was not contemplated when the Deficiency Standards (allowing higher salinity) were included in the Original SMPA. Thus, the Original SMPA does not adequately address impacts to managed wetlands under drought conditions.

The decision was made to amend the SMPA, because of the reasons listed above, and because hydrologic conditions in Suisun Marsh have changed since the original SMPA was signed in 1987. The Amendment would make the channel water salinity standards consistent with the SWRCB's 1995 Water Quality Control Plan, and replace additional large-scale facilities with water and land management activities to meet the objectives of the SMPA in the western marsh. Amendment Three requires amending the Monitoring Agreement to include monitoring required by the new actions and to include SRCD as a participant in the monitoring program. The Mitigation Agreement will also be amended, broadening mitigation activities and funds to include multi-species management.

In September 1995, the SMPA Negotiation Team established a Technical Support Group (comprised of technical staff from the four agencies) to provide data analysis, model studies, and technical input. In January 1996, the Negotiation Team requested that the Technical Support Group identify alternative actions needed to meet the objectives of the SMPA in the western Suisun Marsh. The Technical Support Group prepared a decision matrix of 21 actions, 10 of which are included in Amendment Three. Informal consultations with USFWS resulted in preparation of a Biological Assessment for the Amendment, which was released in Draft form in February, 1999. Formal Section 7 consultation will commence upon completion of a Final Biological Assessment.

In a related but separate process, the SWRCB has included the joint actions proposed in this Amendment as an alternative in the Draft Environmental Impact Report it has prepared for a water rights hearing to implement the 1995 Water Quality Control Plan.

o. 1995 Water Quality Control Plan

In May 1995, the SWRCB adopted the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta estuary (SWRCB 1995). The purpose of this plan is to establish water quality control measures that contribute to protection of beneficial uses in the Bay/Delta estuary. The plan consists of:

- Beneficial uses to be protected
- Water quality objectives for reasonable protection of beneficial uses
- A program of implementation for achieving the water quality objectives

Together, the beneficial uses and the water quality objectives established to protect them are called water quality standards under the terminology of the federal Clean Water Act. This plan supersedes both the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh adopted in August 1978, and the Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta adopted in May 1991. The SWRCB will review this plan every 3 years to ensure that it adequately protects beneficial uses. The SWRCB will implement this plan principally through adoption of a water right decision.

p. 1995 Water Rights Order WR 95-6 and 98-9

On February 28, 1995, DWR and USBR filed a joint petition requesting changes in the water rights that authorize diversion and use of waters affecting the San Francisco Bay/Sacramento-San Joaquin Delta estuary. In April 1995, the SWRCB held a public hearing and received evidence on the key issues listed in the notice. It was decided that Order 95-6 would be an interim order. Its Amendments were to expire upon adoption of a comprehensive water right decision that allocates final responsibilities for meeting the 1995 Bay/Delta objective or on December 31, 1998, whichever comes first. Order 95-6 replaced the water quality standards for fish and wildlife set forth in Water Right D-1485. All other provisions of D-1485 remain in full force and effect.

In June 1995, upon adoption of Order 95-6, SWRCB modified some of the terms and conditions imposed by D-1485 so they conform with new fish and wildlife standards for the estuary set forth in the December 1994 Accord and the 1995 Water Quality Control Plan. Order 95-6 modified the D-1485 Suisun Marsh channel water salinity standards, as revised in 1985, to allow for more saline conditions in the western marsh during dry conditions; defined as the Deficiency Period. The Order also changed the effective compliance date for two western marsh compliance stations to October 1, 1997 (Attachment B of Order 95-6, June 8, 1995). Compliance dates for other marsh stations did not change.

In September 1997, DWR and USBR petitioned the SWRCB for an extension of the effective compliance date for the two western marsh compliance stations. In support of the extension, DWR prepared the Demonstration Document (DWR 1998), which demonstrates how management actions in SMPA Amendment Three will provide equivalent or better protection than channel water salinity standards for western marsh stations. The SWRCB issued an Order approving a temporary change of effective date of compliance through April 1998. In March 1998, DWR petitioned for a second extension, which was granted by the SWRCB through April 1999.

q. 1995 Suisun Ecological Workgroup

The Suisun Ecological Workgroup (SEW) is an ad hoc multi-agency and multi-organization technical work group convened at the request of the SWRCB, as a component of the Program of Implementation in the 1995 Water Quality Control Plan. SEW was convened to address the uncertainty of the effectiveness of the 1995 Water Quality Control Plan delta outflow objectives on tidal wetlands. The workgroup plans to provide a final report to SWRCB by June 1999.

According to the Program of Implementation, the objectives of the Suisun Ecological Workgroup are to:

(1) evaluate the beneficial uses and water quality objectives for the Suisun Bay and Suisun Marsh Ecosystem;
(2) assess the effects on Suisun Bay and Suisun Marsh of the water quality objectives in the Draft Water Quality Control Plan and the federal Endangered Species Act biological opinions;
(3) identify specific measures to implement the narrative objective for tidal brackish marshes of Suisun Bay and make recommendations to the SWRCB regarding achievement of the objective and development of numeric objectives to replace it;
(4) identify and analyze specific public interest values and water quality needs to preserve and protect the Suisun Bay/Suisun Marsh ecosystem;
(5) identify studies to be conducted that will help determine the types of actions necessary to protect the Suisun Bay area, including Suisun Marsh;
(6) perform studies to evaluate the effect of deep water channel dredging on Suisun Marsh channel water salinity;
(7) perform studies to evaluate the impacts of urbanization in the Suisun Marsh on the marsh ecosystem; and
(8)develop a sliding scale between the normal and deficiency objectives for the western Suisun Marsh.

The Suisun Marsh Preservation Agreement Amendment Three and Suisun Ecological Workgroup are parallel processes that focus on different aspects of marsh protection. The Suisun Marsh Preservation Agreement focuses on protection of managed wetlands, while the Suisun Ecological Workgroup is developing recommendations for the SWRCB for comprehensive water quality standards that will be protective of tidal marsh, aquatic, and managed marsh habitats.

r. 1998 Water Rights Order WR 98-9

In December 1998, the SWRCB adopted Order WR 98-9 to extend the provisions of Order WR 95-6, with minor modifications, through December 31, 1999. The following changes were made regarding Suisun Marsh:

- Authorization of a time extension until June 1, 1999 for submittal of the final SEW report.
- Exceedences of objectives at marsh compliance stations during the Suisun Marsh Salinity Control Gate salmon passage experiment will not be considered a violation of water right permit conditions. The experiment will be conducted during the period of October 1998 through May 2001.

Notes the SWRCB order allowing a temporary extension of the effective compliance dates at western marsh compliance stations from October 1, 1998 to April 1, 1999.

s. 1999 Water Rights Decision 1641

In December 1999, the SWRCB issued Water Rights Decision 1641 to implement the water quality objectives in the 1995 Bay-Delta Plan covered in phases 1-7 of the Water Rights Hearings. Decision 1641 supersedes SWRCB Orders WR 98-8 and 95-6. Decision 1641 implements the Suisun Marsh channel water salinity objectives contained in the 1995 Bay-Delta Plan. However, D-1641 removes the requirement to meet the water quality objectives at S-35, S-97, and water supply intakes on Chipps and Van Sickle Island, and instead requires baseline monitoring at these stations. Decision 1641 defers action on the narrative objective for unmanaged tidal marshes until the next periodic review of the 1995 Bay-Delta Plan, when a final report from the Suisun Ecological Workgroup should be available for review.

t. Other SWRCB Orders and Resolutions

In addition to the Decisions and Orders mentioned previously, the SWRCB has issued orders and resolutions to DWR waiving or extending compliance with water quality standards in Suisun Marsh (Table I-5). Condition 6 of D-1485[3] allows for variations in flows for experimental purposes. Under this provision, the SWRCB has granted DWR waivers for various studies in the Marsh, including testing of the effectiveness of the SMSCG and Green Valley Creek flow augmentation, and effects of the SMSCG on salmon migration.

In September 1997, DWR and USBR petitioned the SWRCB for an extension of the effective compliance date for the two western Suisun Marsh compliance stations. In support of the extension, DWR prepared the Demonstration Document (DWR 1998), which demonstrates how management actions in SMPA Amendment Three would provide equivalent or better protection than meeting channel water salinity standards at far western Suisun Marsh stations. The SWRCB issued an order approving a temporary change of effective date for compliance through April 1998. DWR and USBR petitioned, and were granted, additional extensions through April 24, 2000.

[3] D-1641 amended this condition slightly; however, there were no substantial changes in the intent of the condition.

Table I-5. Chronology of State Water Resources Control Board Water Quality Actions in the Suisun Marsh.

SWRCB Action	Date	Substantive Effect for Suisun Marsh	Purpose
Decision 1485	8/78	Water quality objectives at all monitoring stations (C-2, S-64, S-48, S-42, D-7, S-31, S-35, and S-32) effective on 10/1/94	Establishes water quality objectives and water quality monitoring program for Suisun Marsh.
Order	12/5/85	Amends compliance dates for Suisun Marsh standards	Allows time for DWR and USBR to establish monitoring stations.
Condition 6 waiver	9/9/88	Grants DWR exemption to meeting Suisun Marsh water quality standards for the dates of 11/1/88 through 5/31/89.	DWR testing the effectiveness of the SMSCG.
Condition 6 waiver	1/24/90	Grants DWR exemption to meeting Suisun Marsh water quality standards for the dates of 1/24/90 through 5/31/90.	Allows for second year of SMSCG effectiveness testing.
Condition 6 waiver	1/21/94	Grants DWR exemption to meeting water quality standards at stations S-21 and S-97 for the period of 2/1/94 through 5/31/94.	DWR testing effects of Green Valley Creek flow augmentation.
Resolution 94-90	9/22/94	Grants DWR Condition 6 waiver for meeting water quality standards at (1) stations S-49 and S-64 for 10/1/94 through 11/30/94, and (2) stations S-21, S-97, and S-75 for 10/1/94 through 5/31/95. Deficiency standards in effect from December through May at S-21, S-97, and S-75.	DWR testing effects of SMSCG operation on adult salmon upstream migration.
Water Quality Control Plan	5/95	Revised compliance dates for Suisun Marsh Standards	Establishes water quality control measures in the Bay-Delta Estuary
Order 95-6	6/95	Extended compliance dates of S-35 and S-97 to 10/1/97	Interim order to resolve conflicts between D-1485 and the 1995 WQCP.
Temporary Order	10/30/97	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/30/97 through 4/28/98.	Allows for completion of SMPA Amendment 3.
Temporary Order	8/14/98	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/1/98 through 3/29/99.	Allows for completion of SMPA Amendment 3.
Order 98-6	9/17/98	Grants DWR Condition 6 waiver for meeting water quality standards granted for stations C-2, S-64, S-49, S-42, and S-21 during 10/1/98 through 5/31/2001.	Continuation of SMSCG adult salmon migration test.
Order 98-9	12/98	Authorizes extension for final SEW report until 6/1/99. Waives water quality standards for SMSCG salmon test.	Extends provisions of WR Order 95-6.
Temporary Order	4/30/99	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 4/30/99 through 10/27/99.	Allows for completion of SMPA Amendment 3.
Temporary Order	11/1/99	Extends effective date of salinity objectives at S-35 and S-97. Effective dates 10/27/99 through 4/24/00.	Allows for completion of SMPA Amendment 3.

2. History of Permit Authorizations for Activities in Suisun Marsh

a. 1979 San Francisco Bay Conservation and Development Commission Permit Number 35-78(M)

On March 13, 1979, BCDC issued Permit #35-78(M) to DWR for construction and operation of the Initial Facilities, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall (SFBCDC, 1991a).

b. 1979 U.S. Army Corps of Engineers Permit Number 12572-58

On April 12, 1979, the USACE issued 404 Permit #12572-58 to DWR for construction and operation of the Initial Facilities (USACE, 1979).

c. 1981 USFWS Biological Opinion

On December 7, 1981, USFWS issued a Biological Opinion (1-1-81-F-130) to USBR for the Suisun Marsh Plan of Protection.

This Opinion addressed adverse effects on salt marsh harvest mouse (SMHM) (*Reithrodontomys raviventris*) and California clapper rail (CCR) (*Rallus longirostris obsoletus*) from the construction and operation of the facilities ultimately included in the Plan of Protection as well as the maintenance activities routinely conducted in the marsh. The Opinion evaluated four aspects of activities that would likely occur in the marsh: (1) construction and operation of physical facilities; (2) monitoring programs; (3) management programs for the waterfowl hunting clubs in the marsh; and (4) conservation measures.

In the Project Impacts section, the Biological Opinion stated that the project's construction and management activities, as well as implementation of the management plans, could have a significant impact on the SMHM. However, the Biological Opinion also stated that the compensatory actions described in the Suisun Marsh Management Plan to offset such impacts insure the continued existence of the SMHM in the Suisun Marsh. These compensatory actions are:

Retain and manage at least 1,000 acres of preferred SMHM habitat and monitor SMHM habitat marsh-wide every three years, with an ultimate goal of 2,500 acres adequately distributed throughout the marsh. The 1,000 acres retained must meet certain criteria (e.g. 100 percent cover, 50-100 percent pickleweed cover, 40 percent of the marsh useable in the winter with little or no flooding, 80 percent useable for SMHM in the summer). Parcels established for this purpose would range in size from 100 to 500 acres. Monitoring of the SMHM habitat is the responsibility of DFG and is to be coordinated with USFWS.

The Biological Opinion stated that out of a total of 378 acres of wetlands to be created as total compensation for all wetland habitat losses, at least 100 acres of habitat were to be created for the SMHM, with management providing "for the specific habitat requirements" of the SMHM.

Five zones were established in Suisun Marsh to track vegetative composition. If preferred SMHM habitat acreage in any of these zones decreases by one-third, the club management plans would be modified to maintain tracts of SMHM habitat throughout the marsh. Aerial photography and ground truthing would be conducted at 3-year intervals in order to monitor changes in preferred SMHM habitat and determine the need to modify club management plans.

The Biological Opinion stipulates five terms and conditions, with the most notable being #5. This condition requires (1) systematic survey of SMHM populations by monitoring control areas, management areas, and State areas managed for the SMHM; (2) SMHM trapping compatible with the habitat monitoring and aerial surveys; and, (3) coordination with the USFWS on the design of these studies and subsequent data review.

d. 1984 San Francisco Bay Conservation and Development Commission Permit Number 4-84(M)

On June 26, 1984, BCDC issued Permit #4-84(M) for the construction and operation of the SMSCG (SFBCDC, 1991b). Included in the permit was the requirement for DWR to monitor the effects of the project pursuant to a monitoring program prepared by DWR in consultation with DFG.

e. Resolution 85-9

The BCDC certified the existing Individual Ownership Management Plans in Resolution 85-9 under BCDC's certified local protection program. Also, Section 29508 of the Public Resources Code, a section of the SMPA, specifically exempts certain activities in the marsh from the need to obtain a marsh development permit from BCDC. Some of the actions identified in Amendment Three (e.g., repair, replacement, reconstruction, or maintenance that does not result in an addition to, or enlargement or expansion of, the facility) would qualify for this exemption. When the Individual Ownership Management Plans are updated, as described in this Agreement, BCDC would need to re-certify them according to provisions of the Suisun Marsh Local Protection Program.

f. 1986 USFWS Biological Opinion

On March 14, 1986, USFWS issued a Biological Opinion (1-1-86-F-27) in response to USACE request for formal consultation on the construction of the Suisun Marsh Salinity Control Gates and associated levee maintenance and dredge spoil disposal. The opinion addressed the adverse effects on the SMHM from the proposed project. This opinion referenced the 1981 Biological Opinion with regard to impacts on the SMHM and CCR, and stated that "the project, as proposed at that time, remains substantially unchanged. However, USACE authorization, plus the proposed addition of the two dredge spoil disposal sites on Van Sickle Island, introduces new impacts to SMHM that warrant formal consultation."

In the section of the Opinion titled "Effects of the Proposed Project", USFWS stated that the construction and operation of the Suisun Marsh Salinity Control Gates will, in large part; determine future habitat conditions available to SMHM over thousands of acres throughout the Suisun Marsh. Thus, all agreements relating to SMHM protection should be fulfilled or in the process of being fulfilled prior to USFWS endorsement of the project.

g. 1986 U.S. Army Corps of Engineers Permit Number 16223E58

On May 7, 1986, the USACE issued 404 Permit #16223E58 to DWR for construction and operation of the Suisun Marsh Salinity Control Gates. The permit states that the permittee shall perform the reasonable and prudent measures and conservation recommendations as outlined and contained within the 1986 Biological Opinion. Thus, all the Conservation Recommendations in the 1986 Opinion for the Suisun Marsh Salinity Control Gates became binding conditions of USACE authorizations.

h. 1993 National Marine Fisheries Service Biological Opinion

The National Marine Fisheries Service (NMFS) addressed operation of Suisun Marsh Salinity Control Gates in the February 12, 1993, Biological Opinion on the operation of the CVP and the SWP. Included in the NMFS Biological Opinion was the potential for reinitiating consultation to reevaluate impacts of the gates.

i. May 2, 1994 USFWS Letter

In a May 2, 1994 letter, the USFWS further clarified recommendations and maintenance restrictions regarding California clapper rails (CCR) in the Suisun Marsh. The letter states that no adverse effect to the CCR would occur provided that all maintenance activities avoided the CCR breeding season (February 1 through August 31) in locations where CCR were known to occur. This letter specifies four areas, approximately 87,350 linear feet of levee, within the Suisun Marsh of known CCR nesting or breeding locations. The letter also states that breeding season restrictions can be relaxed if surveys completed by a competent biologist in the year that work is anticipated indicate that no CCR nesting territories are within 500 feet of these levees.

j. 1994 USFWS Biological Opinion

On August 29,1994, USFWS issued a Biological Opinion (1-1-94-F-20) to the San Francisco District Office of USACE which addressed the effect on delta smelt (*Hypomesus transpacificus*) and Sacramento splittail (*Pogonichthys macrolepidotus*) due to SRCD's and DFG's periodic maintenance activities within Suisun Marsh. The Opinion states that the effects of the project on SMHM were addressed in USFWS' March 14, 1986 opinion. It further states that the effects on the CCR were addressed in USFWS' May 2, 1994, letter to USACE (1-1-94-I-841).

k. 1994 National Marine Fisheries Service Biological Opinion

On September 21,1994, NMFS issued a Biological Opinion (reference 1-1-94-I-841), to assess the effects on the endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) of the SRCD's and DFG's proposal to perform periodic maintenance activities within Suisun Marsh. The Biological Opinion defined operational and monitoring requirements of the Suisun Marsh Salinity Control Gates. Included in the NMFS Biological Opinion was the potential for the re-initiation of consultation to re-evaluate impacts of the Suisun Marsh Salinity Control Gates.

l. November 24, 1997 National Marine Fisheries Service Letter
This November 24, 1997 letter gives concurrence to proceed with Amendment Three under informal consultation. The Parties incorporated the changes to the Agreement recommended in the letter by NMFS.

m. 1998 DFG Draft Biological Opinion
In May 1998, DFG issued a draft Biological Opinion which assessed the impact of implementing Amendment Three on listed and nonlisted species in the Suisun Marsh. DFG's finding after reviewing the project was that Amendment Three will not have incremental impacts above those of the Original Agreement. The Biological Opinion stated that the Original Agreement and the associated mitigation and permits provide adequate protection to listed and nonlisted species within the Project area. The Biological Opinion found that Amendment Three would not jeopardize the continued existence of any State listed species.

Pursuant to Fish and Game Code Section 2091, DFG identified Reasonable and Prudent Measures (RPMs) as necessary and appropriate to minimize the adverse impacts of incidental takes. These RPMs, which are listed below, were incorporated by DFG into the 1998 Draft Biological Opinion. Any take that is in compliance with these measures and the measures prescribed in the federal Biological Opinion would not be prohibited by the California Endangered Species Act. The RPMs are:

- All conditions and requirements of SRCD’s original Regional General Permit No. R20066E98 for maintenance activities in Suisun Marsh, and its associated biological opinions shall be implemented.

- The last installment of the mitigation funds associated with the Original Agreement shall be used for multi-species management.

- A multi-agency Environmental Coordination Advisory Team shall be established to ensure compliance with required mitigation obligations.

Recent changes in the Fish and Game Code have allowed sections 2090 and 2091 to expire. Until a new code section is adopted, take authorization will need to be provided under Section 2081.

n. Other Miscellaneous Permits
Other miscellaneous permits obtained for activities in the marsh include BCDC permits for installation of water quality monitoring stations, as well as DFG 1601 Streambed alteration agreements and RWQCB 401 Water Quality waivers, as applicable.

D. Physical Facilities

With the adoption of D-1485 in 1978, the DWR and the USBR began to develop physical facilities to achieve internal marsh water quality standards and provide wetland mangers with lower salinity water. In 1979 and 1980, the Department of Water Resources constructed physical facilities collectively known as the "Initial Facilities" - Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall (Figure I-7). In 1984, the Plan of Protection recognized the need to further offset impacts from the operation of the CVP, SWP and upstream water users, and proposed a series of subsequent physical facilities to meet Decision 1485 salinity standards. In the Plan of Protection, facilities to be evaluated for future salinity control were Boynton-Cordelia Ditch, Cordelia-Goodyear Ditch, Potrero Hills Ditch, Grizzly Island Distribution System, and the Suisun Marsh Salinity Control Gates (DWR 1984). The Suisun Marsh Salinity Control Gates were constructed in 1987 and 1988. Due to the effectiveness of the Initial Facilities and the Control Gates, and increased outflows, there are no plans to construct additional large scale facilities. The Initial Facilities and Suisun Marsh Salinity Control Gates are shown in Figure I-7.

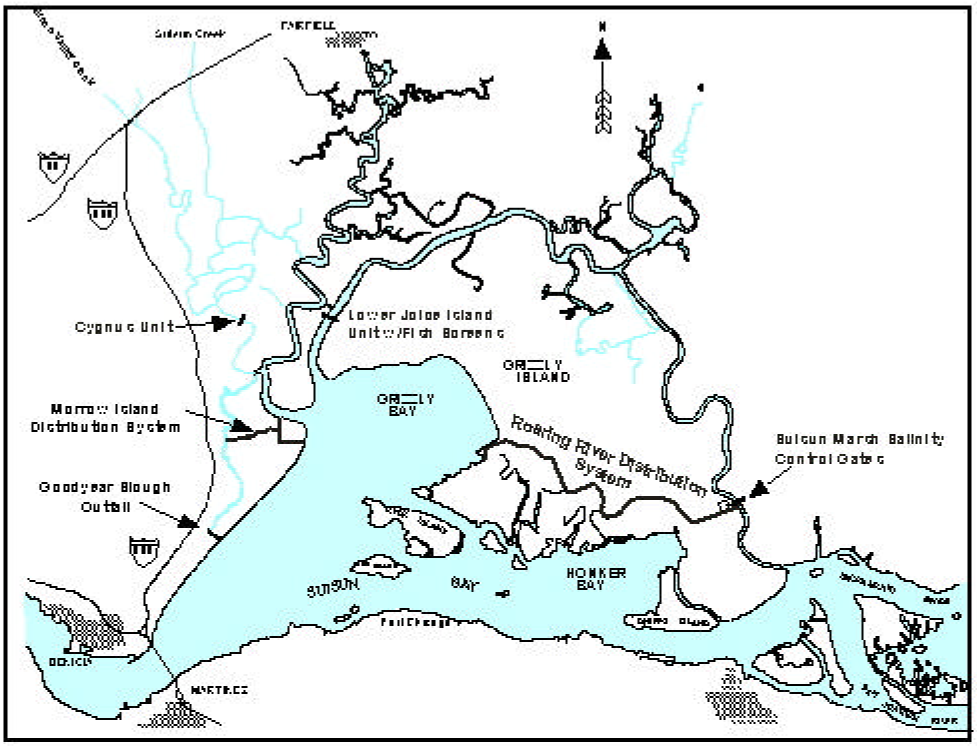


Figure I-7. Suisun Marsh Initial Facilities and Suisun Marsh Salinity Control Gates.

1. Roaring River Distribution System

The Roaring River Distribution System was constructed in 1979-1980 to provide wetland managers on Simmons, Hammond, Van Sickle, Wheeler, and Grizzly islands with lower salinity water. Construction involved enlarging the slough and extending its western end to increase the volume of water available to the managed wetlands. Excavated material was used to widen and strengthen the levees on both sides of the system. A bank of eight 60-inch culverts brings lower salinity water into the system from Montezuma Slough. The culverts are equipped with a fish screen at the intake to minimize diversion of fish into Roaring River Slough. To provide an adequate water supply during fall flood-up, a pond was constructed near the confluence with Montezuma Slough to increase the capacity of the system. This system provides water for approximately 5,000 acres of managed wetlands. The system sustained damage during the February 1998 flood; the levees were repaired during the summer of 1998.

2. Morrow Island Distribution System

The Morrow Island Distribution System, in the western marsh, was constructed in 1979-1980 to make lower salinity water available to the easternmost area of Morrow Island. The system is composed of two channels, known as M-line and C-line, which divert water from Goodyear Slough. The purpose of the system is to allow wetland managers to fill their ponds with lower salinity water from Goodyear Slough or the Distribution System and drain into Grizzly Bay or Suisun Slough. This reduces the introduction of high-salinity drainage water into Goodyear Slough. Maintenance dredging occurred during 1997, and levee repair during 1998.

3. Goodyear Slough Outfall

The Goodyear Slough Outfall was constructed to connect the south end of Goodyear Slough to Suisun Bay. Prior to construction of the Outfall, Goodyear Slough was a dead end slough. The system was designed to increase circulation and reduce salinity in Goodyear Slough and to provide lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water.

4. Suisun Marsh Salinity Control Gates

The objective of Suisun Marsh Salinity Control Gate operation is to decrease the salinity of the water in Montezuma Slough. The Control Gates were completed and began operating in October 1988. The first year of operation was used to test the gates, and official operation began in November 1989. The facility consists of a boat lock, a series of three radial gates, and removable flashboards. The gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the gates in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west. When Delta outflow is low to moderate and the gates are not operating, net movement of water is from west to east, resulting in higher salinity water in Montezuma Slough.

The Control Gates usually begin operating in early October and, depending on salinity conditions, may continue operating through the end of the control season in May. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the gates raised to allow unrestricted movement through Montezuma Slough. Details of annual gate operations can be found in “Summary of Salinity Conditions in Suisun Marsh During Water Years 1984-1992" (DWR, 1994b), or the “Suisun Marsh Monitoring Program Data Summary” produced annually by DWR, Environmental Services Office.

5. Lower Joice Island Unit
The Lower Joice Island Unit consists of two 36-inch diameter intake culverts on Montezuma Slough near Hunter Cut and two 36-inch diameter culverts on Suisun Slough, also near Hunter Cut. Both sets of culverts were called for in the original SMPA and installed in the existing levee in 1991. The facilities include combination gates on the slough side and flap gates on the landward side. The Lower Joice Island facility allows more rapid filling of the site and is connected to the existing distribution system on Individual Ownership Number 424. This facility enables the individual ownership to properly manage its wetlands on Lower Joice Island. Construction of the facility on Lower Joice Island was authorized under SRCD's regional general permit. Under the original SMPA, DWR was responsible for constructing the Lower Joice Island Unit and the individual ownership had the responsibility for operation and maintenance.

6. Cygnus Unit
The Cygnus Unit includes the installation of a 36-inch drain gate with flashboard riser on Individual Ownership Number 415. Installation of this drain gate was authorized under SRCD's regional general permit and installed in 1991. The individual landowner is responsible for operation and maintenance of this gate.

E. Suisun Marsh Monitoring Program

1. Requirements of the Suisun Marsh Monitoring Agreement
The Monitoring Agreement (Appendix A) required the following monitoring using specific methodologies described in Appendix B of the Plan of Protection (Appendix B of this document):

- Channel Water specific conductance (SC): The SC at the Control Stations will be monitored by DWR with continuous recorders...
- Diversion and Drain Water SC: A point on each Monitored Ownership shall be monitored continuously for SC by DWR.
- Pond Water: The SC of standing surface water at each soil water salinity site...shall be determined monthly by DWR.
- Pond Stage: DWR shall maintain a continuous recorder to measure water elevation on each of the Monitored Ownerships. At each of the Control Stations DWR shall maintain a continuous recorder to measure water elevation for five years.
- Soil Water Salinity: Soil water salinity will be monitored monthly by DWR at 40 to 50 sites on Monitored Ownerships[4] and one site on Individual Ownership 423.
- Vegetation Occurrence: The specific composition of vegetation on lands within 35 meters of each soil water monitoring site will be determined by DFG in August or September of each year. The percent of cover contributed by each plant species present on the sample site will be determined by DFG each year.

[4] A "monitored ownership" was a private duck club or state-owned parcel of land which was included in the DWR monitoring program. Each monitored ownership had one or more sites to collect data on soil and pond water SC, water management activities, and vegetation occurrence and production.

- Vegetation Production: The seed production of alkali bulrush and fat hen present on lands within 35 meters of each soil water monitoring site will be determined by DFG each year.
- Tri-ennial (marsh-wide) Vegetation Survey: The overall vegetative composition of the marsh shall be determined by DFG every third year...using aerial photography in conjunction with ground verification...These aerial photos will also be used to determine any net acreage changes in preferred salt marsh harvest mouse habitat...
- Salt Marsh Harvest Mouse Surveys: If the marsh-wide plant survey indicates a significant change...in preferred habitat...then the parties shall determine whether any surveys of the population of the mouse are necessary. If...necessary, DWR will promptly arrange for such surveys to be made.
- Waterfowl Survey: Species and number of waterfowl in the marsh will be determined from aerial surveys carried out by DFG from September through January of each year...
- Young Striped Bass and Neomysis: DWR or DFG will arrange for or conduct studies of the annual abundance of young striped bass and Neomysis in Montezuma Slough.
- Effects of SMSCG on Fish: DWR or DFG will arrange for or conduct studies to determine the impact of predators and disruption of fish associated with the SMSCG.

2. Monitoring Requirements of Other Permits

a. ACOE Permit 16223E58C for Construction of the Suisun Marsh Salinity Control Gates

- Determine the effects of the Control Gates on the aquatic environment.
- Establish the magnitude and nature of delays and predation losses to migratory fish and other indicator species.
- Determine whether salt marsh harvest mouse habitat on the Van Sickle Island has reestablished, by conducting botanical surveys of the dredge spoil sites for three growing seasons after spoil removal to document plant succession and reestablishment.

b. BCDC Permit 35-78(M) for Construction of the Initial Facilities

- A comparison of water and soil salinities within the areas served by the Initial Facilities to the salinities with neighboring areas not served by the facilities, and to measurements taken in years preceding the construction of the facilities.
- An assessment of any significant changes in the composition, diversity, or density of plant and wildlife populations in any area affected by operation of the facilities.

c. BCDC Permit 4-84(M) for Construction of the Suisun Marsh Salinity Control Gates

- Measurements of existing water quality, fish and wildlife resources, and wetland habitat in the marsh that may be affected by the project.
- Measurement of water quality throughout the marsh during operation of the facilities.
- A continuing study of fishery resources and related aquatic life that may be impacted by the project.
- A continuing study of the composition, diversity, and density of plant and wildlife populations within the areas of the marsh affected by the project.

3. Monitoring Network

During the monitoring program covered in this Comprehensive Review (1985-1995), data on salinity and tide stage were collected from a network of sites in Suisun Marsh channels. Soil water salinity, pond water salinity, drainage water salinity, and pond stage data were also collected in the managed wetlands of the monitored ownerships. The channel water SC monitoring stations are shown in Figure I-6 and the monitored ownerships and their associated monitoring sites are shown in Figure I-8. Table I-6 lists the stations that monitored channel water salinity or drain/intake water salinity during the monitoring program.

Information for the monitoring sites in the managed wetlands (the “monitored ownerships”) including active dates of the soil tube sites and pond stage recorders, are listed in Table I-7. Data from the monitored ownerships are presented in detail in Appendices C - P.

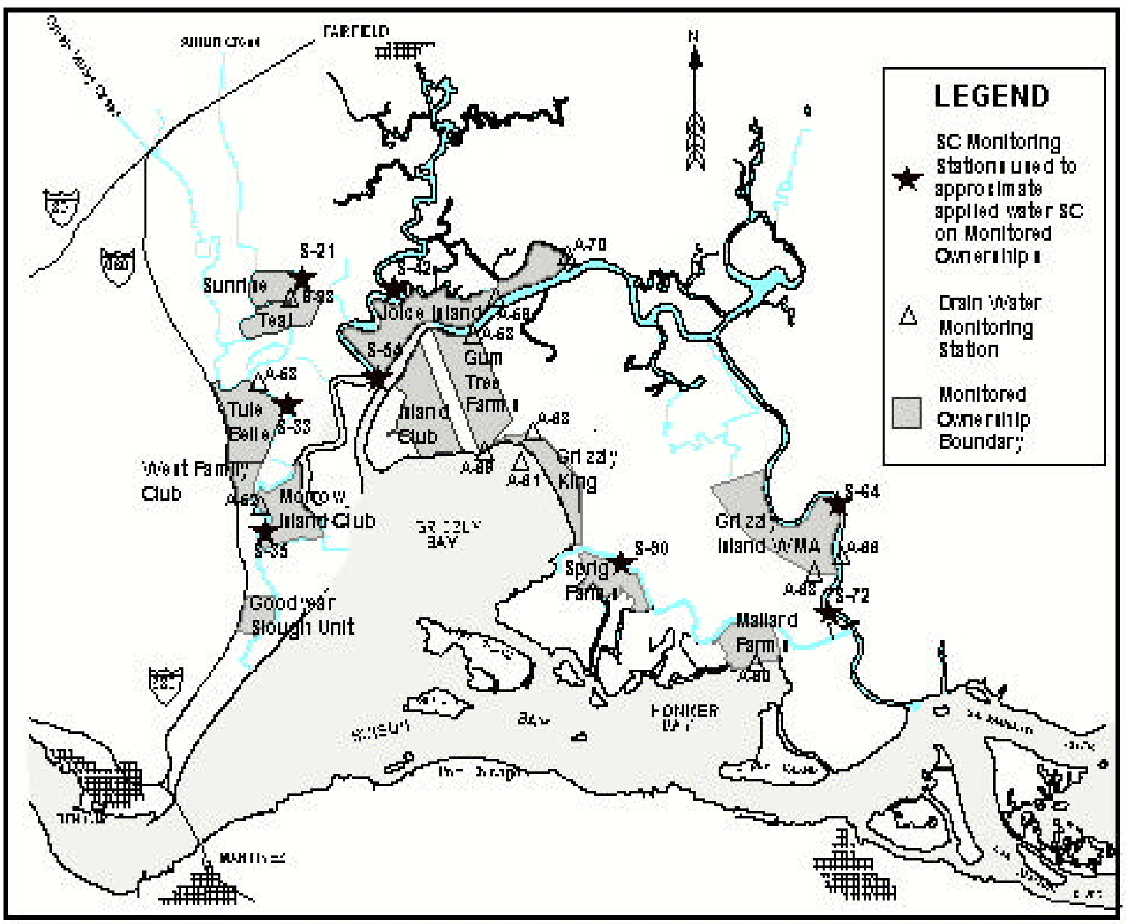


Figure I-8. Monitored Ownerships and Channel and Drain Water Monitoring Stations, DWR Suisun Marsh Monitoring Program.

Data collection on the monitored ownerships began in October 1984, the beginning of the 1985 water year. Forty-five sites were established on eleven ownerships across the marsh. Sites were located in the western, central, and eastern marsh, and were chosen to represent different management practices and soil types. In an attempt to represent different vegetation types, sites were located in areas dominated by alkali bulrush, pickleweed, fat hen, or brass buttons, and in areas of complex vegetative assemblages.

Table I-6. Channel Water SC Monitoring Sites in Suisun Marsh, 1981-1998 (present). For maps of stations see Figures I-6 and I-8.

STATION NUMBER	STATION NAME	ACTIVE DATES		DATES AS COMPLIANCE STATIONS
		FROM	TO	
STATIONS MONITORING CHANNEL WATER SC (See map, Figure I-6)				
	CHIPPS ISLAND @ O&A FERRY LANDING		PRESENT	10/84 - PRESENT
C2	COLLINSVILLE	5/13/85[1]	PRESENT	10/84 - PRESENT
S4	HILL SLOUGH @ GRIZZLY ROAD	01/26/82	PRESENT	N/A
S10	GREEN VALLEY CR. @ GREEN VALLEY RD.	10/04/94	PRESENT	N/A
S15	SUISUN CREEK @ CORDELIA ROAD	03/01/91	01/06/97	N/A
S20	CHADBOURNE SL @ HOLLYWOOD CLUB	04/14/94	07/01/97	N/A
S21	CHADBOURNE SL @ SUNRISE CLUB	02/89	PRESENT	10/93 - PRESENT[2]
S28	TEAL CLUB	10/15/81	PRESENT	N/A
S33	CORDELIA SLOUGH @ CYGNUS	01/20/83	PRESENT	N/A
S34	CORDELIA SLOUGH @ MIRAMONTE	08/94	06/24/97	N/A
S35	GOODYEAR SL @ MORROW ISLAND	03/15/83	PRESENT	N/A
S40	BOYNTON SLOUGH @ BULLSPRIGS CLUB	02/28/92	PRESENT	N/A
S42	SUISUN SL @ VOLANTI SL	01/20/83	PRESENT	10/84 - PRESENT
S49	MONTEZUMA SL @ BELDONS	01/13/83	PRESENT	10/84 - PRESENT
S54	MONTEZUMA SL @ HUNTER CUT	12/07/82	PRESENT	N/A
S64	MONTEZUMA SL @ NATIONAL STEEL	01/21/83	PRESENT	10/84 - PRESENT
S71	MONTEZUMA SL @ ROARING RIVER	07/15/85	PRESENT	N/A
S72	ROARING RIVER @ MONTEZUMA SL	07/23/85	PRESENT	N/A
S90	ROARING RIVER @ SPRIG	10/15/82	PRESENT	N/A
S97	CORDELIA SLOUGH @ IBIS	12/90	PRESENT	10/93 - 5/95[2]
S98	CORDELIA SL @ GARIBALDI	04/94	05/02/97	N/A
A96	GOODYEAR SL @ FLEET	09/16/82	PRESENT	N/A
T20	SUISUN SLOUGH @ GODFATHER II		PRESENT	N/A
STATIONS MONITORING DRAIN AND/OR INTAKE WATER (See map, Figure I-8)				
A52	MORROW ISLAND CLUB DRAIN	10/15/81	06/13/94	N/A
A53	TULE BELLE CLUB DRAIN	01/20/82	05/06/91	N/A
A58	GUM TREE AT CLUB (NORTH) DRAIN	10/15/81	07/90	N/A
A59	JOICE ISLAND DRAIN	12/30/82	07/90	N/A
A60	MALLARD FARMS DRAIN	10/16/81	07/06/92	N/A
A61	GRIZZLY KING DRAIN	10/81	4/88	N/A
A63	F&G GRIZZLY DRAIN (PARKING LOT 8)	01/03/83	07/03/91	N/A
A66	F&G GRIZZLY INTAKE	12/28/82	12/10/90	N/A
A68	GRIZZLY KING CLUB	12/16/82	07/13/92	N/A
A69	GUM TREE INTAKE (SOUTH)	10/15/82	11/01/91	N/A
A70	JOICE ISLAND INTAKE	10/01/82	05/15/91	N/A

1/ Not active 2/87 to 10/88
2/ DWR received a SWRCB variance for meeting standards.

Table I-7. Soil Tube Sites and Pond Stage Recorders in the Suisun Marsh, 1982-1995.

Club	Soil Tube Site #	Active Dates	Pond Stage Recorder #	Active Dates	Drain Water SC Station	Active Dates	Channel or intake water SC Station	Soil type
MORROW	1	8/84 - 9/92	97	10/91 - 10/92	A52	10/81-6/94	S-35	Reyes
ISLAND	2	8/84 - 9/92	75	9/83 - 10/92				Reyes
	3	8/84 - 10/90						Reyes
	4	8/84 - 9/92						Tamba
FAMILY	5	8/84 - 10/90					S-35	Tamba
TULE	6	8/84 - 11/91			A53	11/82-5/91	S-33	Tamba
BELLE	7	8/84 - 9/95	92	9/90 - 9/95				Joice
	8	8/84 - 11/91						Reyes
	9	8/84 - 11/91	76	10/82 - 9/92				Tamba
	10	8/84 - 10/90						Reyes
TEAL	11	8/84 - 10/90			S28		S-21	Tamba
	11a	10/91 - 9/92	95	8/91 - 10/92				
	12	8/84 - 9/92						Tamba
	13	8/84 - 10/90						Reyes
	13a	9/91 - 9/92	77	9/91 - 10/92				
	14	8/84 - 9/92	77	12/82 - 10/92				Joice
JOICE	15	8/84 - 10/91					S-42	Tamba
ISLAND	16	9/84 - 11/91			A59	12/82-7/90	A-70	Tamba
	17	8/84 - 11/91						Tamba
	18	8/84 - 10/91	78	10/82 - 11/90				Reyes
ISLAND	19	8/84 - 11/91			none		S-54	Tamba
CLUB	19a	9/92 - 9/95						
	20	8/84 - 5/93	80	10/82 - 9/95				Tamba
	21	8/84 - 11/91						Joice
	22	8/84 - 11/91						Joice
GUM	23	8/84 - 11/91			A58	10/81-7/90	S-54	Joice
TREE	24	8/84 - 11/91					A-69	Joice
	25	8/84 - 11/91						Tamba
	26	8/84 - 11/91	79	10/82 - 9/92				Tamba
GRIZZLY	27	8/84 - 10/91			A-61	10/81-4/88	A-68	Valdez
KING	28	8/84 - 9/92	82	10/82 - 9/92				Valdez
	29	8/84 - 10/90						Valdez
	30	8/84 - 9/92						Valdez
SPRIG	31	8/84 - 11/91			none		S-90	Tamba
	32	8/84 - 11/91						Tamba
	33	8/84 - 11/91						Valdez
	34	8/84 - 11/91	83	10/82 - 7/92				Joice
	35	8/84 - 11/91	83	10/82 - 7/92				Joice
GRIZZLY	36	8/84 - 10/90			A63	1/83-7/91	S-64	Valdez
ISLAND	37	8/84 - 11/91	87	10/87 - 10/92			A-66	Suisun
	38	8/84 - 10/90	85	10/82 - 7/89				Suisun
	39	8/84 - 10/90						Reyes
	40	8/84 - 11/91	88	10/89 - 10/92				Tamba
	49	11/85 - 9/95	96	9/91 - 9/95				Tamba
MALLARD	41	8/84 - 10/90	84	10/82 - 8/89	A60	10/81-7/92	S-72	Valdez
FARMS	42	8/84 - 9/92					S-90	Suisun
	43	8/84 - 9/92	84A	8/89 - 10/92			in 1987	Joice
	44	8/84 - 11/91						Tamba
	45	8/84 - 9/92						Tamba
WEST	46	11/85 - 9/95			none		S-35	Reyes
FAMILY	47	11/85 - 9/95	93	8/90 - 9/95				Reyes
GOODYEAR	48	11/85 - 9/95	94	8/91 - 9/95	none		S-35	Reyes
SUNRISE	50	10/92 - 9/95	98	12/92 - 9/95	none		S-21	Tamba
	51	10/92 - 9/95						Tamba

A pond stage recorder was installed on ten of the eleven ownerships, and stations to measure the specific conductance of drain water were placed on seven ownerships (Figure I-8, S28, A52, A53, A58, A59, A60, A63). Most sites had three soil tubes installed to collect water at a depth of 6" below the soil surface. Four sites had one tube each at depths of 3, 6, and 9 inches, which were used to determine whether the 6" tubes collected a representative sample of the water in the top 12" of soil. The first foot of soil was chosen as the interval of interest because most water management in the marsh was tailored to favor the growth of alkali bulrush (*Scirpus maritimus*), which has a root zone of approximately one foot.

In November 1985, two ownerships (two sites on West Family and one on Goodyear Slough Unit) and an additional site on Grizzly Island (49) were added to the program. These four sites were managed for fat hen (*Atriplex triangularus*) rather than alkali bulrush. Because fat hen's roots grow deeper than those of alkali bulrush, three soil tubes were set to collect soil water at each of three depths, 6, 18, and 30 inches. These sites did not have pond stage recorders installed until water year 1991 (West Family) or 1992 (Grizzly Island and Goodyear Slough Unit).

The Suisun Marsh Monitoring Agreement states that "monitoring on Individual Ownerships shall terminate on September 30, 1990 unless the parties mutually agree otherwise". In 1990 it was decided that further data collection was needed to help confirm the relationships between surface water salinity and soil water salinity, and the program continued with some adjustments. Two pond stage recorders were added, one was removed, and eleven soil tube sites were dropped because access was difficult, the site was rarely flooded, or data collected at the site were duplicated at another site on the same ownership.

At the beginning of water year 1992, nineteen sites were dropped from the monitoring program, leaving nineteen sites on nine ownerships. In water year 1993, twelve sites were dropped, and two sites on a "new" ownership (Sunrise Farms) were added, for a total of nine sites on six ownerships. These sites were monitored for the next three years, until all on-site monitoring ended in September, 1995.

4. Quality Assurance/Quality Control

Quality Assurance/Quality control procedures were incorporated when the monitoring program was designed. These procedures were mainly confined to laboratory practices.

a. Quality Control

Quality control (QC) pertains to the activities whose purpose is to control the quality of measured data so they meet the needs of the monitoring project.

Field Quality Control. Field QC activities are those conducted in the field to ensure data quality. These activities may include procedures for sample collection as well as field quality control samples such as duplicates and blanks. The individual QC activities conducted for each monitored parameter are discussed in their respective chapters.

Laboratory Quality Control. Laboratory QC activities are those activities conducted by the analytical laboratory to ensure data quality. These may include analysis of laboratory QC samples as well as following established standard operating procedures for each analysis.

b. Sample Representativeness

The purpose of this report, in part, is to evaluate the relationship between applied water, pond water, and soil water salinity. In order to provide useful information, the samples collected must be representative of environmental conditions. EPA defines representativeness as "The degree to which the data accurately and precisely represent a characteristic of a population parameter, variation of a property, a process characteristic, or an operational condition". Sample representativeness is evaluated in the Data Evaluation Section of each applicable chapter.

c. Laboratory Data Validation

All salinity analyses were conducted by the Department of Water Resources' Bryte Chemical Laboratory. Independent evaluation of the laboratory QA/QC was not performed; however, routine procedures were conducted by Bryte Laboratory to assess the data quality.

Laboratory data were evaluated for precision and accuracy. Precision is the degree to which the measurement is reproducible among replicate observations. Bryte Laboratory routinely determines precision by running duplicate tests on samples within the sample set. Accuracy is a determination of how close a measurement is to the true value. Accuracy is evaluated by analysis of spiked samples. Sample spikes are prepared by addition of a known amount of a standard solution to a sample. The spiked and unspiked samples are then analyzed for the parameter of interest. Precision and accuracy assessment utilizes control charts and well established statistical procedures.

d. Conclusion

Based on evaluation of the quality assurance/quality control practices, it appears that the data are of acceptable quality for use in this study. Unfortunately, field quality control samples were not collected to provide an evaluation of the sampling procedures. In addition, independent evaluation of the laboratory QA/QC data was not performed. Limitations of individual data sets based on sample representativeness and/or method evaluation are discussed in the Data Evaluation section of the applicable chapters.

5. Unsuitability of the Data for Statistical Analyses

In 1992, Dr. Ted Foin of the Department of Environmental Studies, University of California at Davis, reviewed the data collected on the monitored ownerships (pond water salinity, soil water salinity, pond stage, vegetation occurrence and production) and found that the data were not rigorous enough for significant statistical analysis, and that even non-parametric analysis would probably result in very weak correlations. His conclusions were:

Vegetation data are too coarse (wide-net) to assess impacts of salinity on plant composition or seed production. Increased salinity induces physiological changes in plants over the year. Vegetation measurements taken just once per year do not assess all environmental variables, so it is not valid to link changes seen to any one parameter (such as salinity).

Temporal and spatial variation in data collection is too great to allow significant comparisons to be made. Differences in time scale exist because sampling has taken place over several years. Internal heterogeneity (microsite variation) is too great. Within-club variation (among soil tube sites) of soil water salinities is greater than between-club variation.

The data collected are not appropriate for discovering relationships between water salinity and plant productivity. Determining salinity-vegetation relationships would require shifting the focus from a spatially intensive wide-net program to a locally intensive program where selected stands of vegetation would be monitored more intensively throughout the year.

Other limitations of the data include lack of duplicate samples (pond and soil water) to provide a more accurate representation of field conditions, non-random location of sampling sites, and data gaps caused by equipment malfunctions or inaccessibility of the monitoring sites.

As a result of Dr. Foin’s assessment, the data from the monitored ownerships will be used only to assess general trends in salinity or vegetation changes over the study period.

Chapter II
Channel Water

A. Water Quality Standards

In 1985, specific conductance (SC) standards just outside and within the Suisun Marsh were established by State Water Resources Control Board Decision 1485. With the implementation of D-1485, the following SC compliance standard became effective at Chipps Island.

> "The 28-day running average of mean daily electrical conductivity[1] at O&A Ferry Landing on Chipps Island (or equivalent) shall not exceed 12.5 mmhos October - May, except that the comparable electrical conductivity shall be 15.6 mmhos from October - December in any calendar year when the Central Valley Project or State Water Project water contractors are taking a deficiency in Scheduled Water."

D-1485 also defined compliance standards for eight internal marsh stations. The standards were based on the monthly average of both daily high tide SC values (progressive daily mean, PDM), which is reported on the last day of each month and reset on the first day of the subsequent month. These standards and the deficiency standards from the Suisun Marsh Preservation Agreement are listed in Table II-1. The deficiency standards were in place when the SWP or CVP water contractors were taking a deficiency in Scheduled Water. These standards were amended on June 8, 1995 by SWRCB Order WR 95-6, however all the data analyzed in this document were collected prior to this date, so the effects of Order WR 95-6 are not discussed here.

B. Channel Water Specific Conductance Data Evaluation

1. Method Description

The Suisun Marsh Monitoring Agreement required monitoring of high tide channel water specific conductance (SC) at nine sites in the marsh and two sites on the Sacramento River (Figure I-6, Table I-5).

Specific conductance (SC) and tide stage data were continuously monitored at 15-minute intervals at each of the required monitoring sites in the marsh. Tide stage data from selected sites were measured using a stilling well and float system and recorded using

[1]Electrical conductivity is the ability of a substance (water) to conduct an electrical current. Various ionic species in water, such as calcium, magnesium, sodium, chloride, sulfate, and carbonate, and their concentrations, directly affect the conductivity of water. Electrical conductivity also increases with temperature due to the increase in kinetic energy of ions in solution. Therefore, electrical conductivity provides an indirect measure of salinity at a given temperature. Specific conductance (SC) is electrical conductivity corrected to a standard temperature of 25 degrees Celsius. The electrical conductivity standards in Decision 1485 are required to be measured as SC, therefore, all salinity measurements in this report are SC values. SC is measured in mho/cm which is electrical conductivity divided by the distance (usually 1 cm) between two platinum electrodes. Under the International System of Units conductivity is reported in siemens/cm. Siemens and mhos are numerically equivalent. The unit milliSiemen per cm (mS/cm) is most often used in this report.

Environ Lab DL-150 or DL-800 data loggers or Fisher-Porter or Stevens punch paper tape recorders. SC was monitored by similar recorders modified to accommodate an SC sensor. Data tapes and computer files were stored and processed through computerized operations. All monitoring equipment was converted to direct digital output and digital recording in 1998.

Table II-1. Decision 1485 Salinity Standards and Suisun Marsh Preservation Agreement Deficiency Standards for Internal Marsh Compliance Stations (Mean Monthly High Tide Salinity).

Month	Decision 1485 and Preservation Agreement Normal Standards (mS/cm)	Preservation Agreement Deficiency Standards* (mS/cm)
October	19.0	19.0
November	15.5/16.5	16.5
December	15.5	15.6
January	15.5	15.6
February	8.0	15.6
March	8.0	15.6
April	11.0	14.0
May	11.0	12.5

*Deficiency standards were in effect when (1) a Critical Year followed a Dry or Critical Year, or (2) a Dry year followed a year in which the Four Basin Index was less than 11.35, or (3) the second consecutive Dry Year followed a Critical Year.

2. Quality Assurance/Quality Control

Quality assurance/quality control measures for the channel water salinity monitoring consisted of weekly instrument calibration against laboratory standard solutions. Quality control for tide stage measurements consisted of weekly calibration checks and periodic resurveying of station benchmarks.

3. Sample Representativeness

Monitoring stations were located throughout the marsh in an effort to provide an accurate representation of conditions across the marsh. Placement of the stations appears to have provided representative data, with the exception of the northeastern portion of the marsh, where data coverage is lacking. Therefore, the extent to which this area has been affected by operation of the facilities cannot be addressed.

Data from selected channel water monitoring stations in the marsh were used to represent applied water SC at various monitored ownerships. Table II-2 lists the channel water monitoring station used to represent applied water quality at each monitored ownership. Figure I-8 shows the locations of the monitored ownerships and respective monitoring stations.

Table II-2. Monitored ownerships and associated monitoring stations used to approximate applied water SC.

Monitored Ownership(s)	SC Monitoring Station
Mallard	S-72 RR at Montezuma Slough
Grizzly Island WMA	S-64 National Steel
Sprig	S-90 RR at Sprig
Grizzly King	A-68 Grizzly King
Joice Island	S-42 Volanti
Island Club, Gum Tree	S-54 Hunter Cut
Teal, Sunrise	S-21 Sunrise
Tule Belle	S-33 Cygnus
Morrow Isl., West Family, Goodyear	S-35 Morrow

With the exception of Mallard, Gum Tree, and Goodyear, the monitoring stations are located next to, or fairly close to, the intake for the associated monitored ownership(s) and thus provide SC values representative of the applied water. The representativeness of station data for the aforementioned three monitored ownerships is discussed below.

a. Mallard Farms
Mallard Farms is located approximately 2 miles downstream of station S-72 along the Roaring River Distribution System (RRDS). Station S-72 monitors the channel water conditions in the RRDS at the point of input from Montezuma Slough. Since there are no other sources of water entering the RRDS other than Montezuma Slough, the channel water SC at S-72 should be representative of conditions further down the system at the Mallard Farms intake.

b. Goodyear
A situation similar to that of Mallard Farms exists for Goodyear, which is located approximately one mile south (downstream) of station S-35. Although Morrow Island Club diverts water from Goodyear Slough, it’s management plan calls for drainage into the Morrow Island Distribution System (MIDS), which discharges into Grizzly Bay, and therefore should not impact Goodyear Slough SC. No sources of water enter Goodyear Slough between S-35 and the MIDS intake, so channel water SC at S-35 should be representative of SC of water at the intake to Goodyear.

c. Gum Tree
The intake to Gum Tree is located on Montezuma Slough, approximately 2 miles east (upstream) of S-54. The intake and drain for Island Club are also located along Montezuma Slough, directly across the Slough from S-54. Therefore, channel water SC at S-54 may be affected by drainage from Island Club, as well as upstream drainage from Gum Tree. Consequently, there is the potential for more saline channel water conditions to exist at S-54 than exist upstream at the Gum Tree intake. However, this may not be a significant concern, because ponds do not simultaneously drain and flood, except during

circulation. When ponds are circulated, drainage water is not likely to affect the channel water SC since the volume of drainage water is small compared to channel water volume. In addition, since most ownerships followed a similar management schedule, it is not likely that Island Club would be draining while Gum Tree is flooding. Therefore, the SC values measured at the monitoring stations are considered representative of the SC of the water applied to the managed wetlands.

4. Data Limitations

Based on the method evaluation and Quality Assurance/Quality Control, the data appear to be acceptable for their intended use.

C. Channel Water SC Data Results

Compliance standards were in effect each water year from October through May.

1. 28-Day Running Average SC at Chipps Island

The October to December deficiency standard (15.5 mS/cm) was in effect at Chipps Island during water years 1987 to 1993. Starting in water year 1992, there was a January 1-27 ramp-down period during deficiency periods to provide a gradual transition from the 15.6 mS/cm standard in December to the 12.5 mS/cm standard in January.

Annual graphs of the SC at Chipps Island and the D-1485 standards are shown in Figure II-1 (a and b). The graphs show that during a dry year following a wet year (WY85), SC at C2 gradually increases through the year. Wet years that follow dry years (1986, 1993) begin the water year with high SC (10 to 13 mS/cm), decrease rapidly as outflow increases, and end the water year with SC at about 5 mS/cm. The dry years from 1987 to 1992 all showed a similar general trend of high SC (usually 8 to 12 mS/cm) in the fall, winter, and summer with an annual low of about 1 mS/cm lasting only a month or two in the spring. For the period of record, SC at Chipps Island was below the D-1485 standard, except during February and March 1991, when the 28-day running average SC exceeded the 12.5 mS/cm standard by less than 2 mS/cm. Additional discussion is contained in Section 3, below.

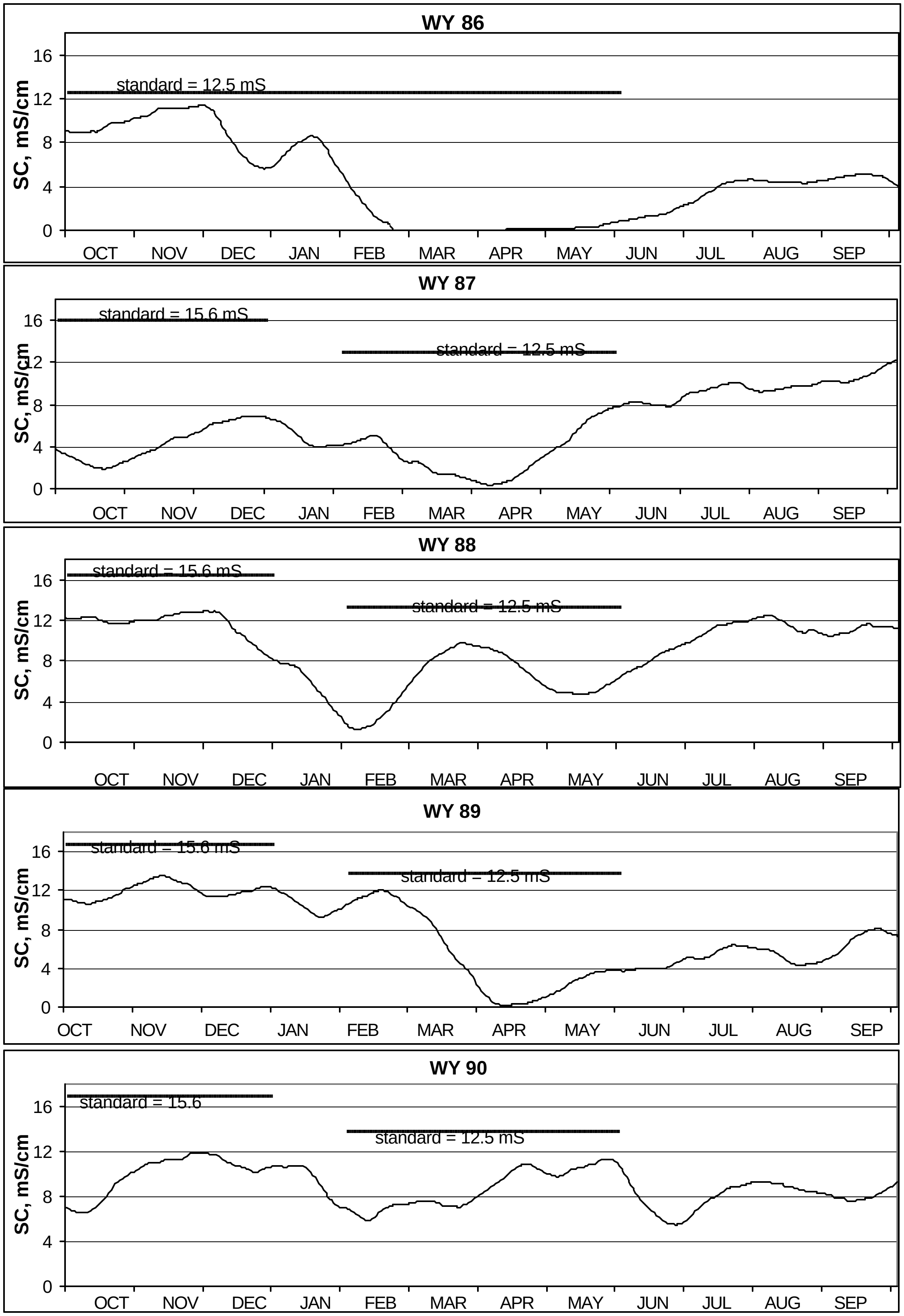


Figure II-1a. Chipps Island 28-Day Running Average Specific Conductance (SC) for WY86-90.

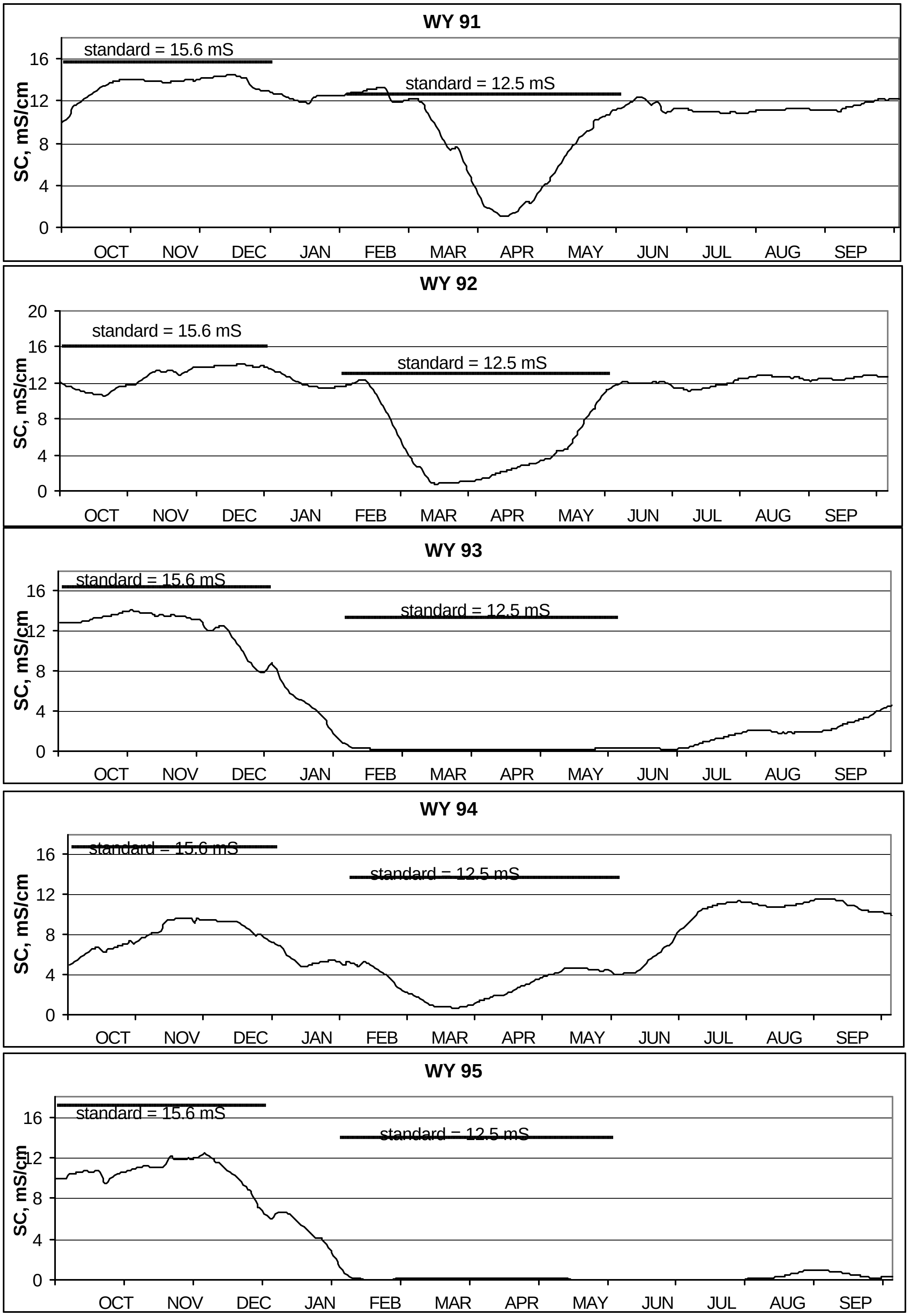


Figure II-1b. Chipps Island 28-Day Running Average Specific Conductance (SC) for WY91-95.

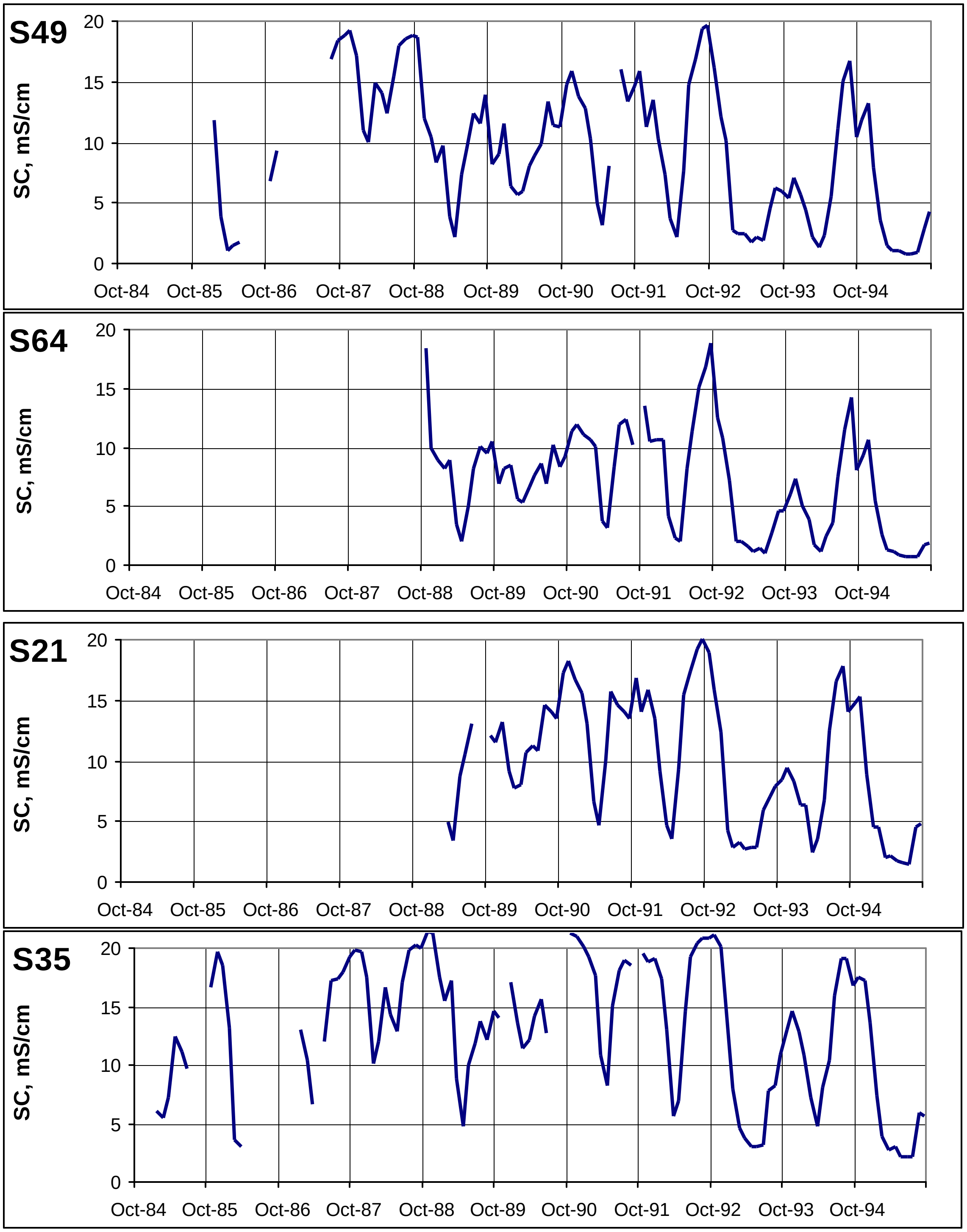


Figure II-2. Monthly Progressive Daily Mean (PDM) specific conductance (SC) for four Suisun Marsh channel water monitoring stations, Water Year 1985-1995.

2. Monthly Mean High Tide SC at Internal Marsh Stations

Channel water SC throughout the marsh follows the following general pattern: SC values reach their annual peak during the late summer and fall, decrease rapidly to their annual low in the late winter and early spring, then increase through the late spring and summer. This trend can be seen in Figure II-2 which shows individual line graphs of the mean monthly high tide SC at the internal marsh monitoring stations S64 and S49 in the eastern marsh, and S21 and S35 in the western marsh.

At most times, the SC (mean monthly high tide) recorded at marsh stations increase from east to west in this order: S64, S49, S21, S42, S33, S35/S54. The trend for western marsh stations to have higher SC than eastern marsh stations is demonstrated in Figure II-3, which compares SC at S49 and S35, and shows that SC at S35 is usually higher than that at S49.

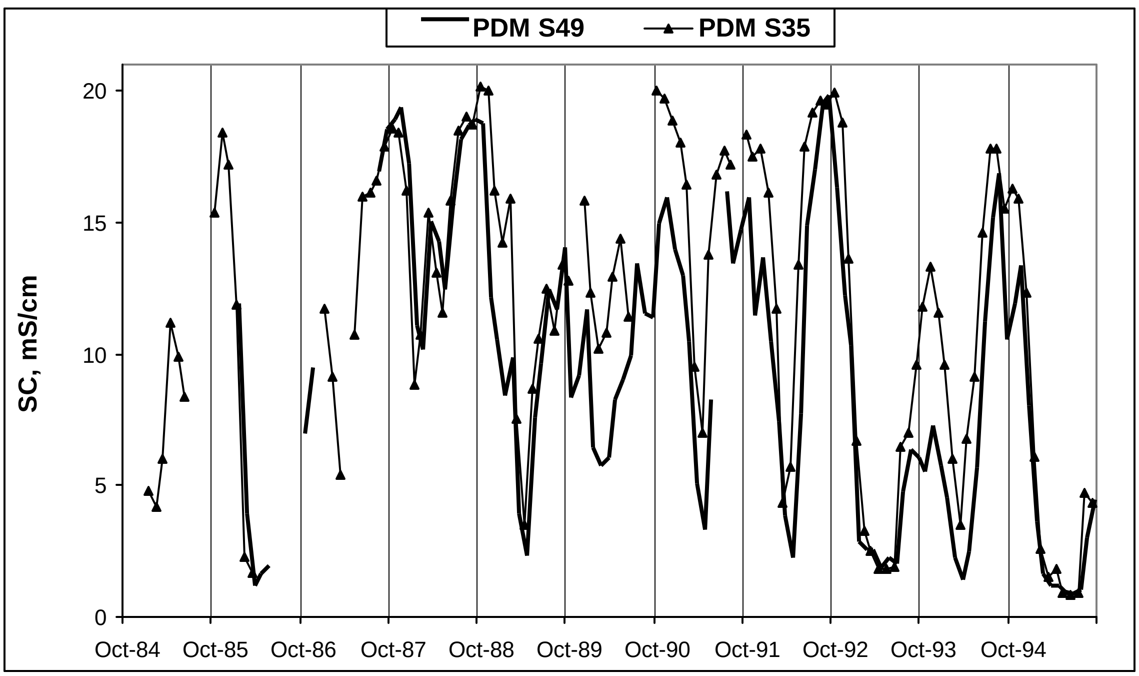


Figure II-3. Mean monthly SC (PDM, progressive daily mean) at two compliance stations, WY85 to WY95. S49 is in the eastern Suisun Marsh, S35 in the western marsh.

SC (mean monthly high tide) values for water years 1985-1995 for eastern marsh compliance stations C2, S64, and S49 are shown in Figure II-4. Figure II-5 shows the same information for western marsh monitoring stations S21, S97, and S35. Both figures include a bar chart for each station and both the D-1485 and SMPA deficiency standards. The western stations were compliance stations only during 1994 and 1995, but the compliance standards are included for all years in Figure II-5 to show when western marsh SC exceeded compliance targets. (In 1994, stations S21 and S97 were compliance stations, but DWR received a variance from SWRCB, and meeting the standards was not required.)

To compare long-term trends in SC at the monitoring and compliance stations across the marsh, monthly values (mean monthly high tide SC) were averaged for each water year at each station. These values are graphed in Figure II-6 for three eastern marsh stations and in Figure II-7 for four western marsh stations. Both eastern and western marsh stations displayed the same general trend over the monitoring period.

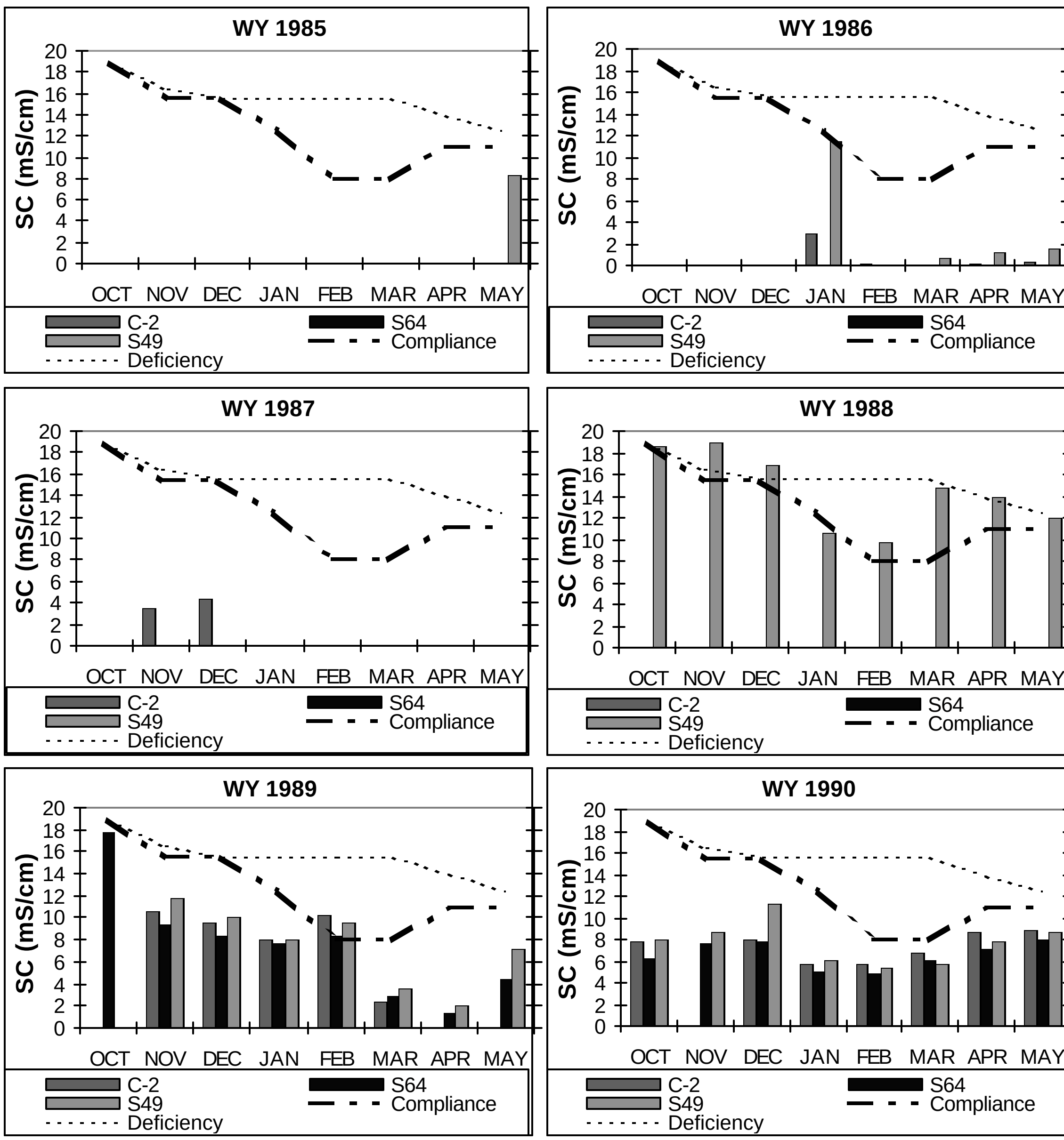


Figure II-4a. Suisun Marsh monthly high tide PDM (progressive daily mean) from stations in eastern marsh, WY85-90.

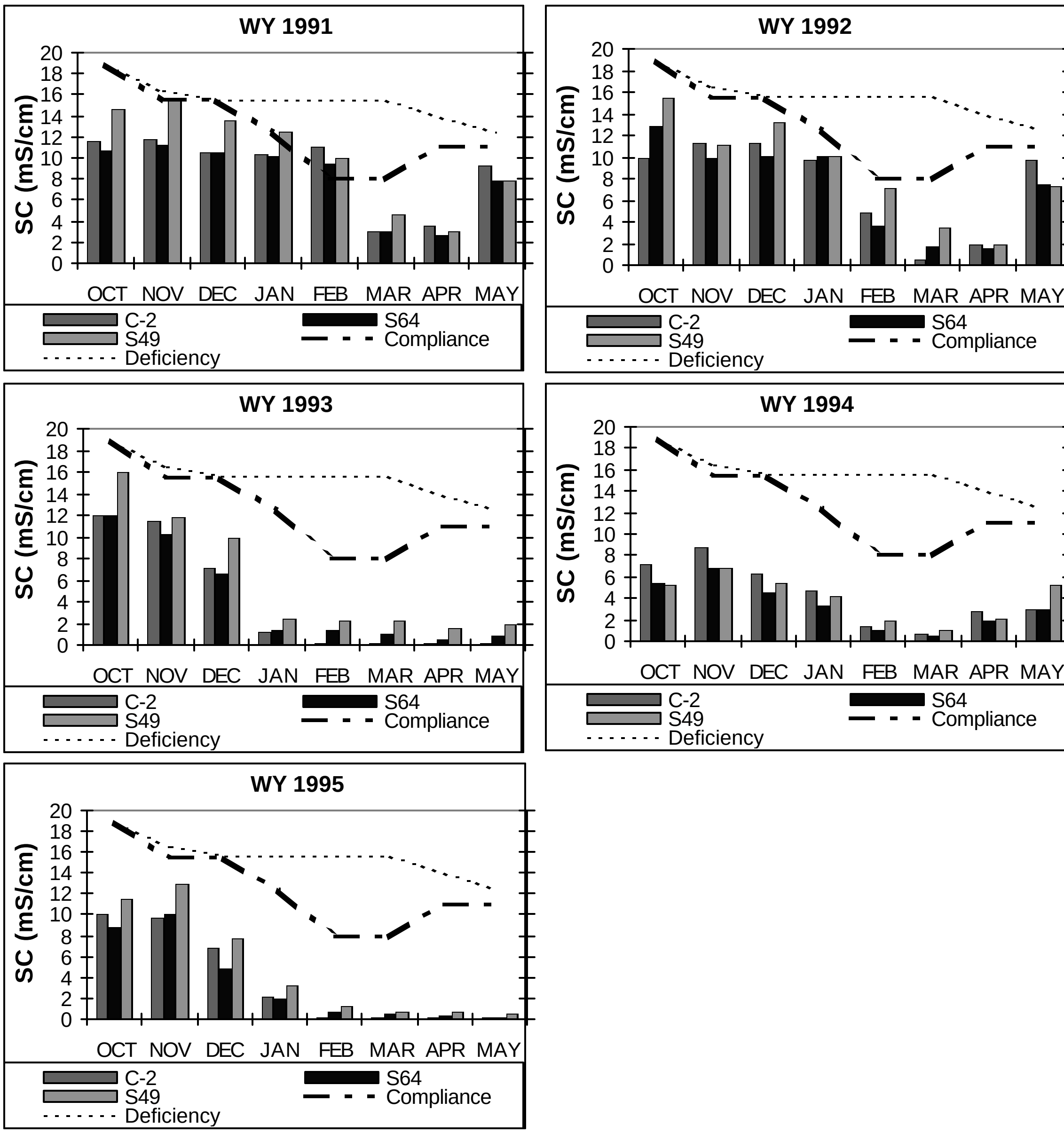


Figure II-4b. Suisun Marsh monthly high tide PDM (progressive daily mean) from stations in eastern marsh, WY91-95.

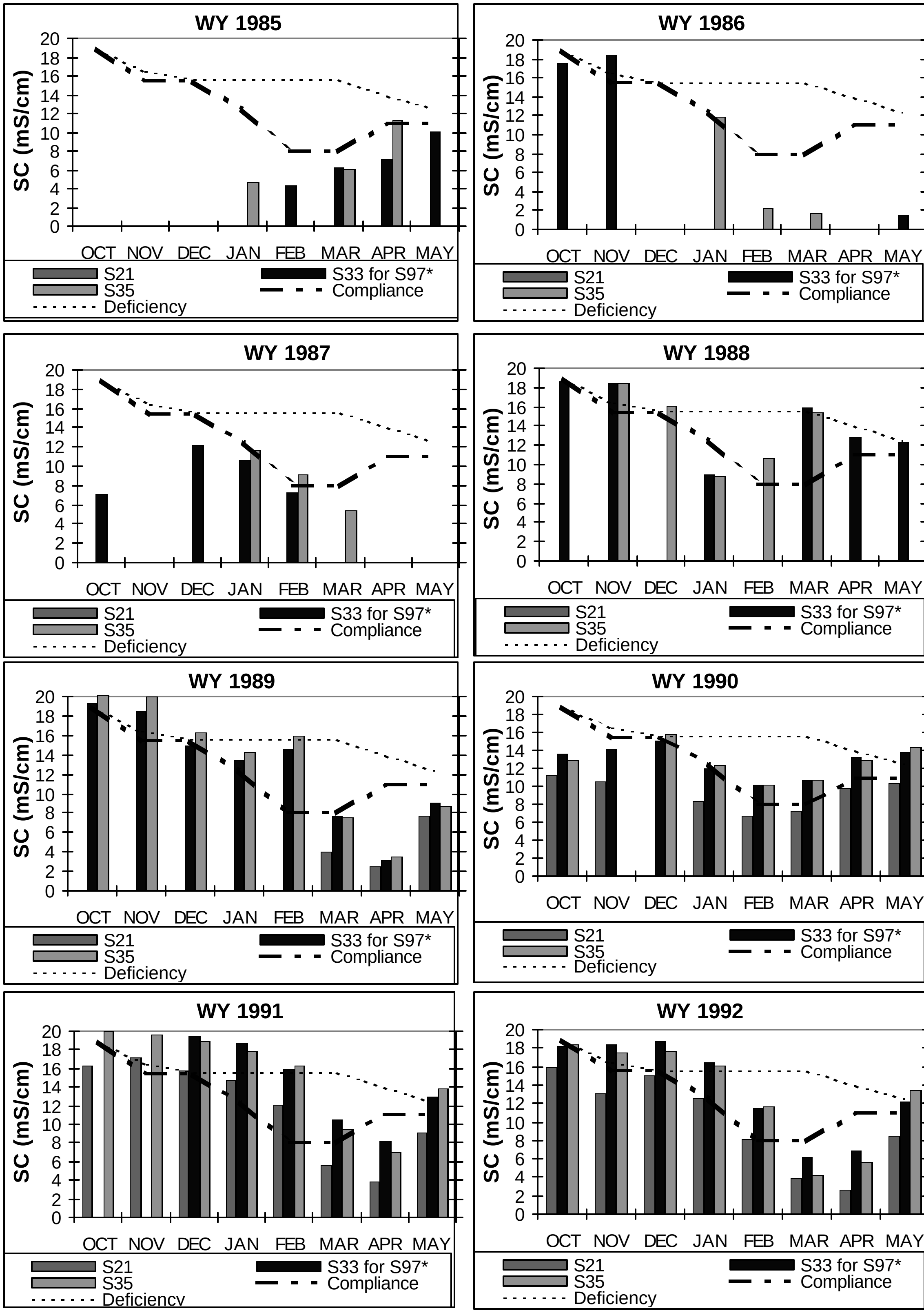


Figure II-5a. Suisun Marsh monthly high tide PDM (progressive daily mean) from stations in western marsh, WY85-92.
*** SC at station S33 substituted for station S97 until 1991.**

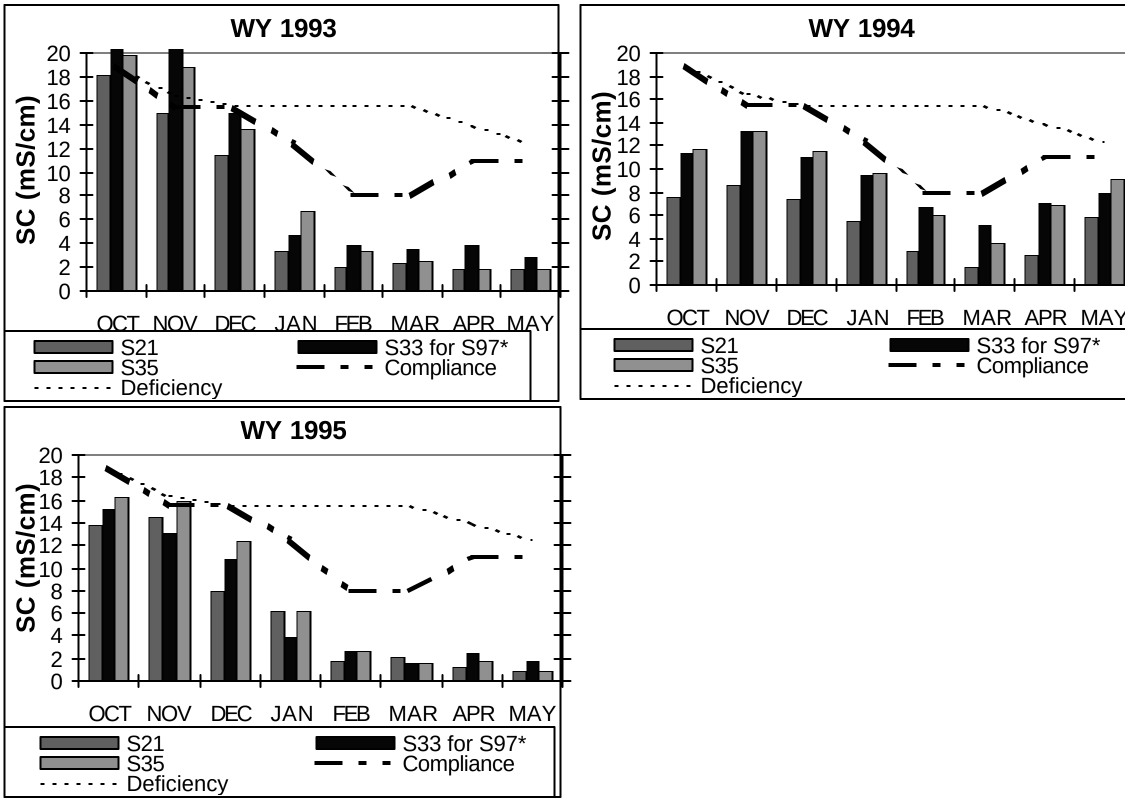


Figure II-5b. Suisun Marsh monthly high tide PDM (progressive daily mean) from stations in western marsh, WY93-95.
*** SC at station S33 substituted for station S97 until 1991.**

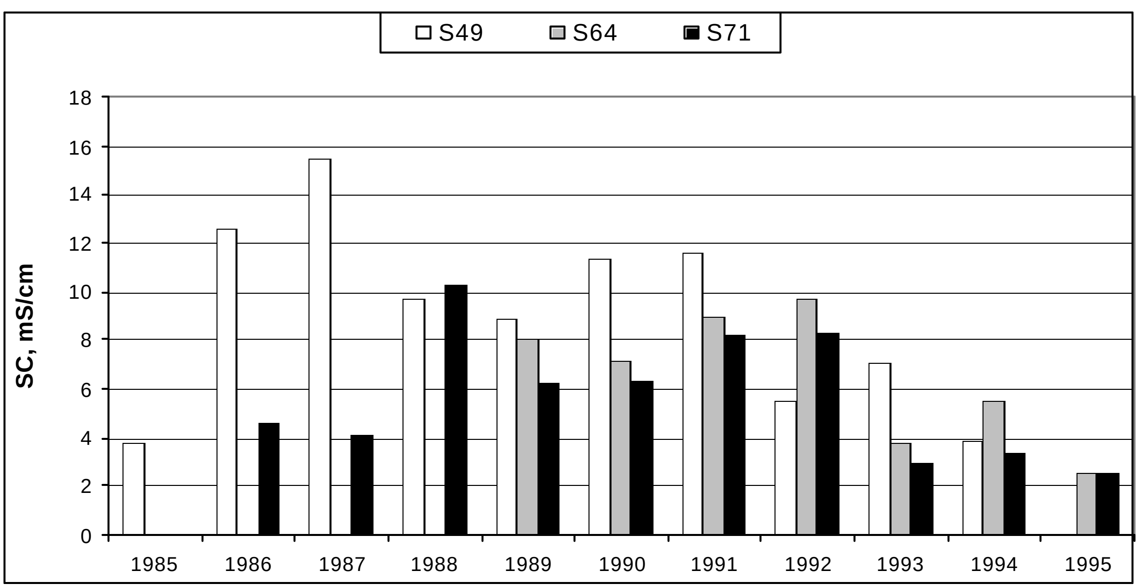


Figure II-6. Annual average PDM at three eastern Suisun Marsh SC monitoring stations WY85-95.

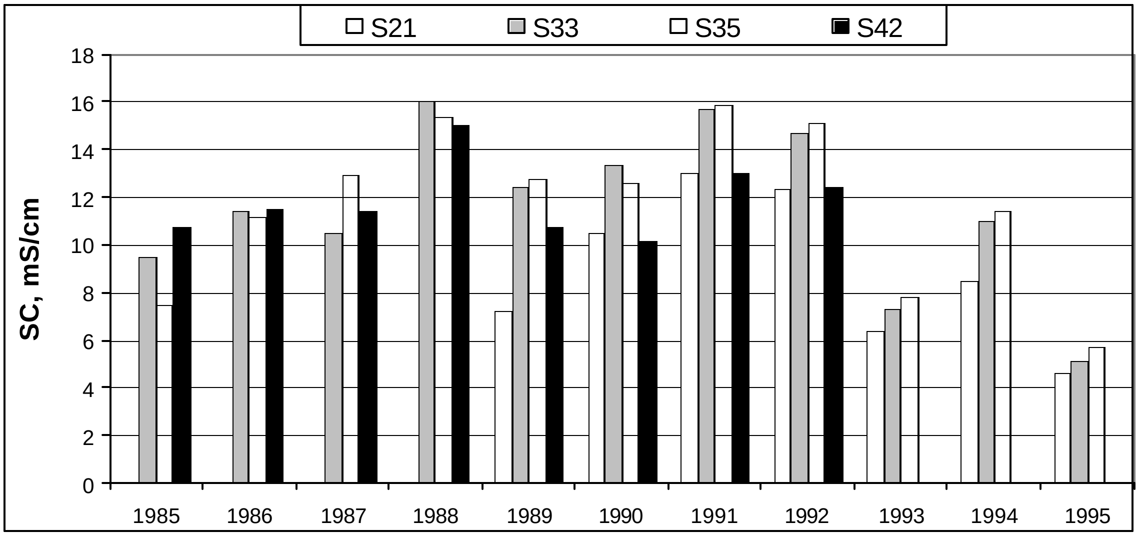


Figure II-7. Annual average PDM at four western Suisun Marsh SC monitoring stations WY85-95.

3. Relationships Between Suisun Marsh Channel Water SC, Delta Outflow and SMSGC Operation

Delta outflow and SC data for Suisun Marsh compliance and monitoring stations C-2, S-49, and S-35 are presented from July 1985 through December 1995 in Figure II-8. Although there are some data gaps at some stations throughout this 10 year period, the expected trend of lower SC during periods of higher outflow is consistent throughout the years shown.

Operation of the Suisun Marsh Salinity Control Gates is also shown on Figure II-8. Full-bore operation means that all three gates are open during an ebb tide and closed during flood tide. The gates began operating in October 1988 and full bore operation continued through mid-March 1989. During this period, and other periods of full bore operation, SC at both S-49 and C-2 decreased.   Although SC reductions at S-35 were less pronounced, it does appear that operation of the gates does affect SC at S-35. The reduction is thought to be a result of the reduced tidal prism caused by operation of the SMSCG.

Two testing periods occurred in the early years of SMSCG operation to evaluate the effectiveness of the facilities. The results of these two tests were submitted in two separate reports to the State Water Resources Control Board, Effectiveness of the Suisun Marsh Salinity Control Gates 1989 and 1991 (Vader 1989, Brown 1991).

Gate operation was also modified in the beginning of the 1993 water year to test the effectiveness of partial gate operation. Partial gate operation consisted of one or all three of the gates left partially open during times when they typically would have been closed. Gate operation was also modified for the 1993 and 1994 Adult Salmon Migration Studies and for maintenance of the facility throughout the years. Other than these periods, the SMSCG was operated as needed to control SC in the Suisun Marsh during the compliance season.

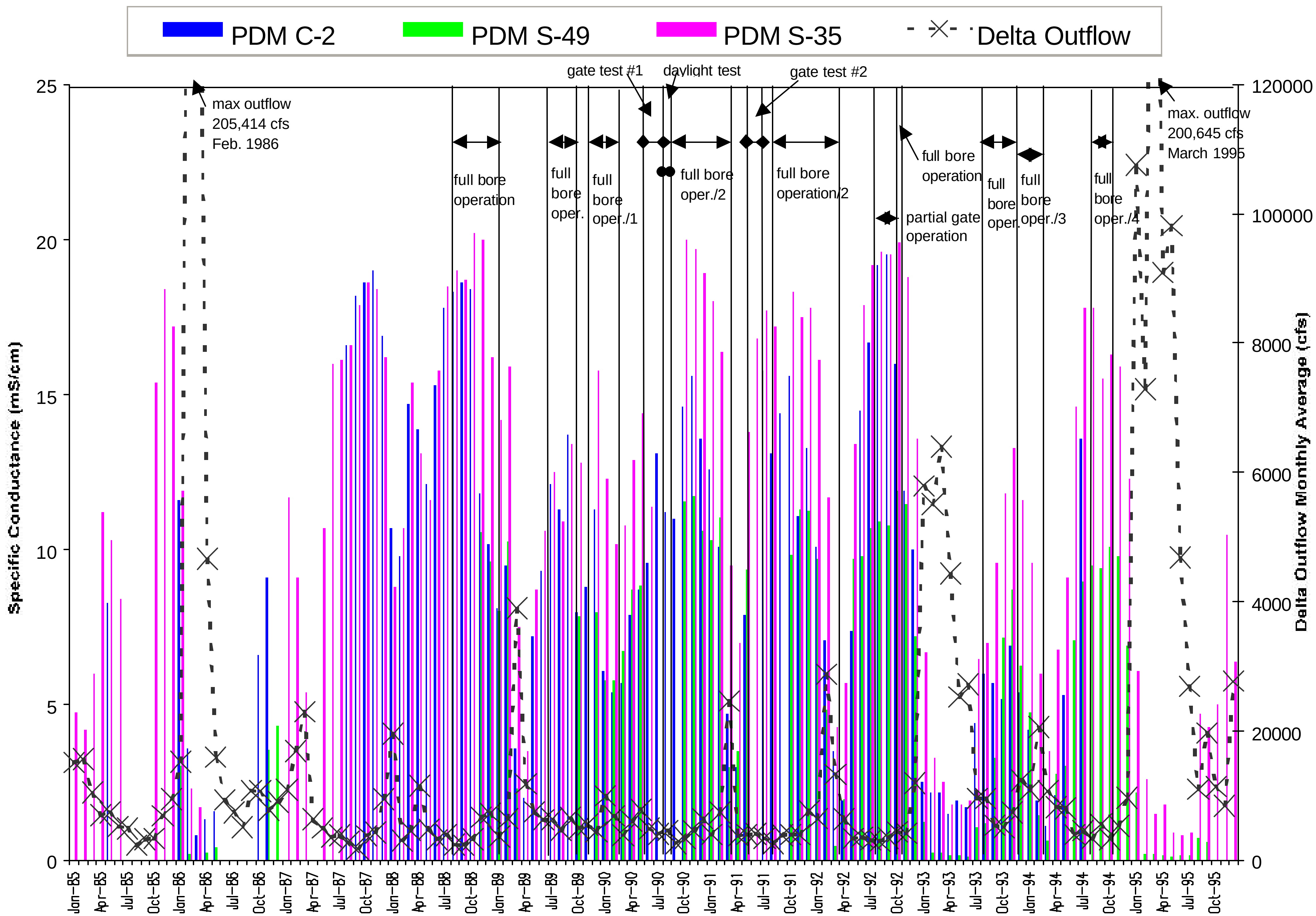


Figure II-8. Suisun Marsh Specific Conductance (PDM, progressive daily mean or mean monthly high tide) and Delta Outflow, July 1985 through December 1995.

1/ Full bore operation except 12/89
2/ Full bore operation with interruptions for repairs
3/ Two gates full bore, one gate under repair
4/ Salmon study

4. Exceedences of D-1485 or SMPA Standards

Between January and March 1991, D-1485 compliance standards at Chipps Island, C-2, S64, and S49 were exceeded (Table II-3a). A variance had been requested during this time to temporarily relax the standards to the D-1485 and SMPA deficiency standards while the Control Gates were tested under conditions of low Delta outflow. However, all signatures to the variance request were not received in time, and the test went ahead without the variance. The resulting exceedences were discussed at a SWRCB hearing, and the SWRCB concluded that there were no adverse impacts because of the short duration of the exceedence and its small magnitude.

There were also exceedences of the normal standards during November and December 1987 and February 1988 and1989. However, SWRCB variances were in effect during these times, and the SC did not exceed the values stipulated in the variances (Table II-3b).

Table II-3a. Exceedences of Suisun Marsh SC Standards, WY 1985-1995.

Station	Date	Station SC	D-1485 Standard
Chipps	Feb/March 1991	14	12.5
C2	February 1991	11.0	8.0
S64	February 1991	9.5	8.0
S49	November 1990	15.6	15.5
S49	January 1991	12.6	12.5
S49	February 1991	10.1	8.0

Table II-3b. Allowed* Exceedences of Suisun Marsh SC Standards, WY 1985-1995.

Station	Date	Station SC	D-1485 Standard
C2	February 1989	10.2	8.0
S64	February 1989	8.4	8.0
S49	November 1987	19.0	15.5
S49	December 1987	16.9	15.5
S49	February 1988	9.8	8.0
S49	February 1989	9.5	8.0

*These exceedences occurred when SWRCB variances were in effect.

D. Conclusions

The requirements of the Monitoring Agreement and D-1485 were met by the Monitoring Program. The collected data fulfilled the compliance function for the D-1485 and 1995 Water Quality Control Plan standards. A number of other DWR reports discuss Suisun Marsh channel water SC trends in detail, including:

- Suisun Marsh Monitoring Program Data Summaries (published annually by Environmental Services Office [ESO])
- Estimate of Salinity Changes in Suisun Marsh for Water Years 1987-1992 with CUWA/AG Criteria, ESO, January 4, 1994
- Summary of Salinity Conditions in Suisun Marsh During Water Years 1984-1992, ESO, November 23, 1994.

E. Recommendations

The data collected are adequate for the monitoring requirements. Currently the channel water SC in the northeastern portion of the marsh is not monitored adequately. An additional monitoring station in this area would provide valuable information on salinity and hydrology, and on effects of the SMSCG on small sloughs in this area of the marsh, which are important habitats for native fishes.

Chapter III
Pond Stage Data

Pond stage recorders were located in twelve ponds managed for waterfowl hunting throughout the Suisun Marsh. These sites were usually inundated for several months of the year. Pond water elevation data were collected on the monitored ownerships from October 1984 through September 1995. A discussion of the monitoring method, data quality evaluation, and results follows.

A. Pond Stage Data Evaluation

1. Method Description

The Monitoring Agreement required continuous stage water level recorders to be installed on the monitored ownerships to document the timing and duration of drain and flood cycles. After 1992, the depth of leach cycles was also monitored.

Pond stage recorders (PSR) were monitored using a float system. Water level data were recorded using an ink-pen-on-drum style Stevens Type F recorder. Pond stage charts were retrieved monthly from the field, and provide graphical records of on-site water management practices.

2. Quality Assurance/Quality Control

Despite occasional mechanical and operator errors, the pond stage recording system provided reliable information on pond water depth. The accuracy of the PSRs was checked monthly against a staff gauge installed at each site. Data from PSRs were usually consistent with staff gauge readings at the time of site visits. Float and recorder systems were inspected and corrected or recalibrated when discrepancies were found between the two readings.

3. Sample Representativeness

Because the elevation of the pond bottom varies, the data collected are accurate only in the immediate vicinity of the PSR. In some cases the recorder was placed in an area that was atypical of the pond, such as a low spot that recorded higher water depths than the rest of the pond; consequently leaching events were not observable (e.g. PSR 85 at Grizzly Island, PSR 76 at Tule Belle).

4. Data Limitations

The pond stage records were the only data collected on water management actions such as leaching, flood duration, and depth of flooding. The records are assumed to be accurate, although the only comparisons made between the records and actual conditions were comparisons between PSR readings and staff gauge levels during the monthly visits to the sites.

There were several assumptions applied to interpretation of the pond stage records:

- Water levels increase when (1) the intakes are open and water enters the pond from the exterior channel, or (2) it's raining.
- Water levels decrease when (1) the drains are open and the pond water empties into the exterior channel, and (2) water evaporates.
- When both intakes and drains are kept closed, the water level in a pond should slowly decrease due to evaporation and infiltration and increase only when it rains.

The PSR data are not adequate for determining when the monitored ownerships were circulating the water in the ponds, because water levels in the ponds don't change significantly during circulation. Data on circulation periods would have been useful in determining when the ownerships were taking on water from the channels. Without this information it is difficult to accurately assess the relationships between channel, pond, and soil water SC.

In July 1992, SRCD requested that the pond stage wells be deepened to monitor the depth of leach cycles. The Stevens PSR is not designed to measure subsurface water levels, but DWR and SRCD agreed that the instrument might at least provide an indication of the depth and duration of leach cycles. Just prior to water year 1993, the float wells were deepened to 1.5 feet below the surface. The resultant pond stage records do show a response to subsurface water levels, but these cannot be taken as a reliable measure of the water table elevation.

B. Data Results

With the exception of the following discussion on precipitation effects, PSR data will generally not be discussed separately, but will be discussed as it relates to effects on pond water quality and leaching events (Chapters 4 and 6).

A review of the PSR data indicate that precipitation can affect the management of the diked wetlands by increasing pond water depth, and possibly interfering with leaching and draining efforts. Figure III-1 shows a typical relationship between precipitation and pond water depth. In general, PSR data indicate it takes about 2" of rain in one day, or a storm lasting several days with about an inch or more of rain each day, to realize an increase in pond depth. At these precipitation levels, the increase in pond depth is roughly half the precipitation amount. The clubs can sometimes mitigate the effects of precipitation by opening their drains, but not all ponds have the drainage capability to keep precipitation and runoff from accumulating. In addition, high water levels in channels and sloughs during significant storm events can interfere with drainage.

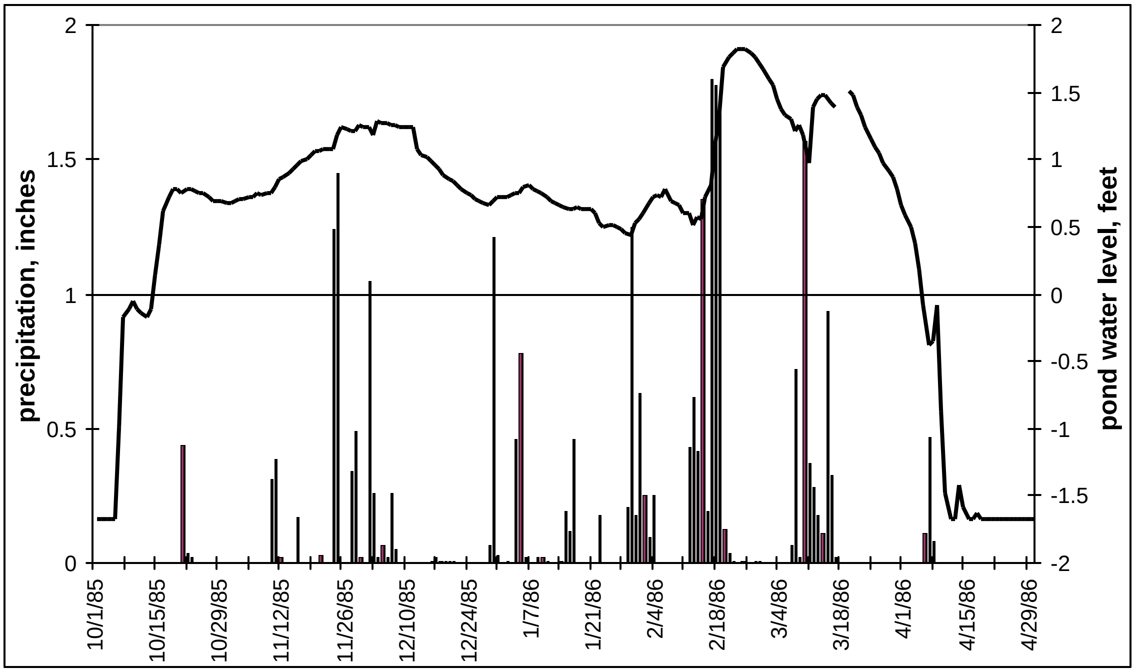


Figure III-1. Grizzly Island Site 38, WY86 daily pond water level and precipitation.

C. Conclusions

Strictly, the requirements of the Monitoring Agreement pertaining to pond stage elevation were met by the Monitoring Program, although there were limitations to the data collected. The data collected were inadequate to determine when circulation occurred. In some cases pond depth measurements at the PSR were non-representative of overall conditions in the pond and were not suitable for evaluation of leaching operations.

D. Recommendations

Although the Stevens drum style recorder was state of the art when the monitoring program was initiated, there are currently several technologically advanced methods of recording pond stage data, including subsurface water levels. These new instruments include computer data loggers so that the data are quickly transferable to a computer database.

Future pond stage monitoring should either include more measurement stations in each pond, or hydraulic assessment should be performed so that a representative site is selected.

Chapter IV
Pond Water Specific Conductance

Pond water SC was measured throughout the marsh in diked areas managed for waterfowl hunting. The ponds where data were collected, called monitored ownerships, were usually flooded for several months of the year. Pond water SC data were collected from 14 monitored ownerships from August 1994 to September 1995.

A. Pond Water Specific Conductance Data Evaluation

1. Method Description

The Monitoring Agreement required that the SC of standing surface water at each soil sampling site be determined monthly. During monthly site visits, when water was present in the pond, a one pint grab sample of surface water was collected. Pond water pH was measured with a Beckman pH 21 pH Meter. Pond water specific conductance was measured using a Beckman RC 20 Conductivity Meter. These measurements were performed by field technicians prior to sending samples to the DWR Bryte Chemical Laboratory. Most pond water specific conductance values in this report are those obtained from Bryte Laboratory.

2. Quality Assurance/Quality Control

a. Field Quality Control

EPA methods for sample collection, preservation, and handling of water were followed (USEPA 1993).

b. Laboratory Quality Control

Laboratory quality control procedures listed in EPA methods were followed (USEPA 1993). This included the analysis of the following: laboratory blanks, laboratory quality control samples, matrix spike samples, and duplicate samples. DWR's Bryte laboratory follows standard operating procedures to assess the accuracy and precision of all analytical procedures.

3. Sample Representativeness

Pond water SC was evaluated from a single grab sample of pond water collected from the surface. Since the ponds were generally shallow, with a usual water depth of about 1 foot, significant SC stratification was not a concern. When SC at sites within a pond were fairly uniform throughout the pond this was assumed to indicate effective circulation, and grab samples were assumed to be representative of pond SC. Some monitored ownerships did not routinely circulate the pond water, and the grab samples may not provide an accurate estimate of SC throughout the pond.

Since samples were only taken once per month, the SC of the sample may not have been representative of the actual monthly pond water SC. For example, if an intake was opened a few days before the date of collection, the pond water at the time of collection may have been significantly less saline than over the entire month. This potential sample bias cannot be evaluated since there were no data collected on the effects of water management actions on pond water SC.

4. Data Limitations

No data quality limitations were found. However, because samples were collected as monthly grab samples, they represent only the SC at the time of collection. Changes in SC over the month are not available; consequently, short-term, immediate effects of management or precipitation cannot be evaluated. These considerations also limit the suitability of the data for assessment of long-term changes or trends in pond water SC.

B. Data Results

This section does not include discussion of the data collected at sites 5, Family Club or sites 50 and 51, Sunrise Club. These data were not used because these sites were monitored for only a short time, and did not contribute to the long term data analysis.

1. Temporal Specific Conductance Trends

To evaluate long-term trends in pond water SC, graphs of pond water SC and water year were prepared for each site (see figures, including site location maps, in Appendices C-P). A regression analysis was performed to determine if there was a significant linear trend in SC over time. This analysis does not infer a causal relationship between time and SC, and was used only to evaluate linear trends in SC over time. January through June monthly pond water SC values were averaged for each site and water year. Only the months of January through June were used, because this is the period when the effects of water management are apparent. From October to mid-January, the ponds are flooded for hunting season and pond water SC undergoes substantial fluctuations. Leach cycles and other water management actions which affect pond water SC are conducted from late January through March to June, depending on the management scheme.

Pond water SC was considered to show a definite linear trend over the monitoring period if the coefficient of determination or R^2 value was equal or greater than 0.8. Sites with R^2 values less than 0.8 were not considered to have a definite linear trend over the entire monitoring period, but may show trends for portions of the study period.

Almost all sites had fluctuating annual average (Jan-June) pond water SC over the study period, with no linear pattern or trend (see graphs in appendices C-P). Only one site, Gum Tree Site 25, had a definite linear increasing trend over the monitoring period; none were decreasing or stable. At Gum Tree site 25, annual average pond water SC increased during the monitoring period, 1985 through 1991, with an R^2 value of 0.83 (Figure IV-1).

Although no other site had definite trends over the entire study period, there were common trends in pond water SC over portions of the study period. Trends in pond water SC for the monitored ownerships are described in the appendices.

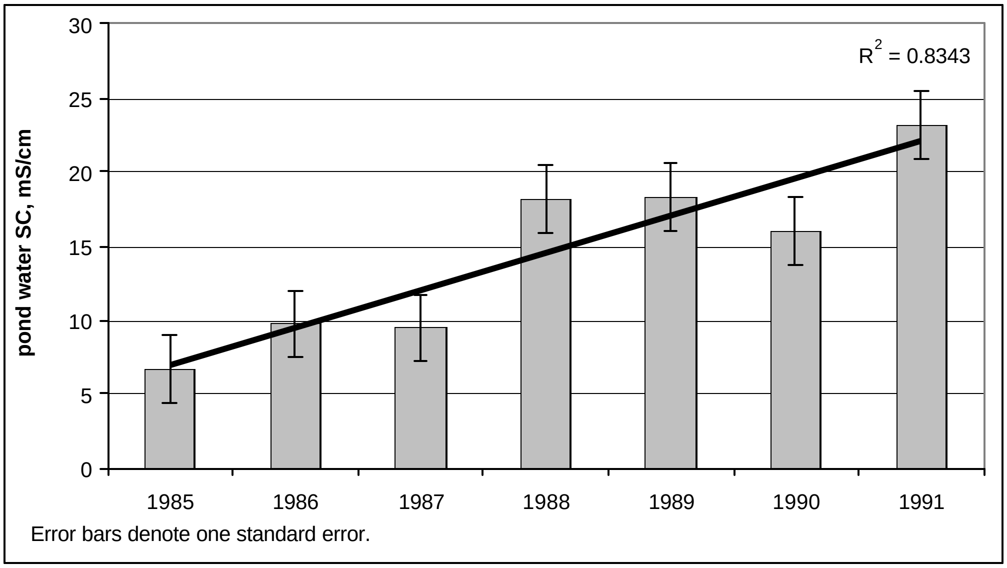


Figure IV-1. Annual average (Jan-June) pond water SC at Gum Tree Site 25, with trendline showing increasing trend.

To provide a general indication of pond water SC trends in the marsh from 1985 to 1995, January to June pond water SC values from all sites were lumped together and averaged for each year (Table IV-1a). The October to December lumped average are shown in Table IV-1b to show the difference in pond water SC during (Table IV-1b) and after (Table IV-1a) flood-up. The average (Jan-June) marsh-wide pond water SC began to increase in 1987, which was the beginning of six years of drought (dry or critical water years). It is interesting to note that pond water SC did not decrease in 1993 when the drought ended, but did decrease significantly in 1995. It appears that there was a delayed pond water SC response to decreased channel water SC.

Table IV-1a. Marsh-wide ranges and averages of January-June pond water salinity averages in mS/cm.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
N=*	29	34	31	28	36	32	29	13	5	4	6
Avg of Jan-June avgs	6	8	12	16	14	14	16	14	13	13	7
Range	3-15	3-12	4-38	7-23	5-25	6-29	7-27	9-24	11-15	11-15	5-12

*yearly data sets for sites with less than 3 data points were not included in calculation of averages

Table IV-1b. Marsh-wide ranges and averages of October-December pond water salinity averages in mS/cm.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
N=	44	47	47	47	45	47	37	17	7	7	7
Avg of Oct-Dec avgs	5	15	9	17	20	13	19	19	21	12	15
Range	1-10	6-25	2-22	11-36	10-33	7-19	11-25	10-25	18-24	8-16	8-17

2. Spatial Specific Conductance Trends

Channel water SC in Suisun Marsh tends to increase from east to west. To determine if there was a similar trend in pond water SC with respect to geographical location, annual average (Jan-June) pond water SC values for each ownership were plotted in order from east to west for each year (Figure IV-2). Grizzly King was not included because it was flooded with water from Grizzly Bay. Prior to 1988, Gum Tree also flooded from Grizzly Bay, so it is included only for water years 1988 through 1991. As can be seen in Figure IV-2, pond water SC across the marsh was fairly variable. Generally, ponds in the western portion of the marsh had higher pond water SC values than ponds in the eastern marsh, but this was not statistically significant or consistent. During water year 1985, which followed three wet years, pond water salinities were low and fairly similar across the marsh. With the exception of Goodyear (where the pond water SC almost doubled), similar values were measured in water year 1986, a wet year. Pond water SC increased and became more variable beginning in water year 1987 and continued this trend (increasing in variability and value) through water year 1991. From 1987 to 1992 the water years were either dry or critical. From water year 1992 to 1995, pond water SC decreased and was fairly uniform across the marsh, due to the higher outflow, increased precipitation, and low channel water salinities of water years 1993 and 1995. Pond water SC values in 1995 were similar to the low values of 1985 and 1986.

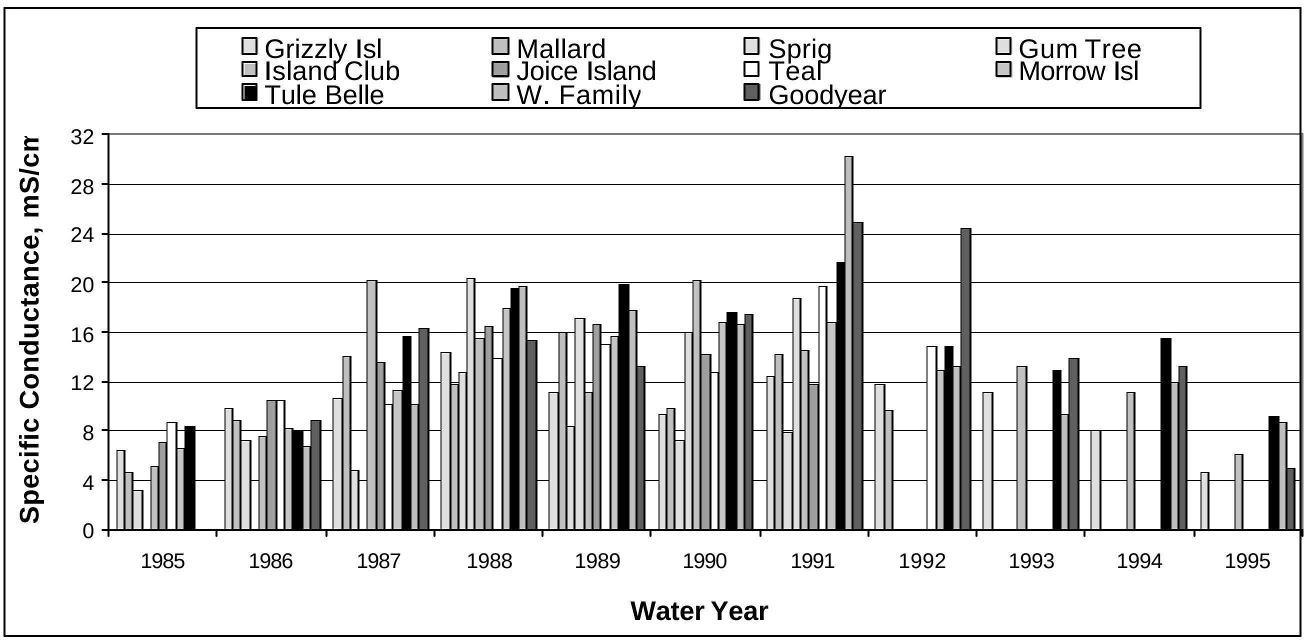


Figure IV-2. Annual average pond water SC (Jan-June) with monitored ownerships arranged in order from east to west.

Annual pond water SC averages (Jan-June) for all sites over the monitoring period were ordered by increasing pond water SC. Annual pond water SC ranged from 3 to 31 mS/cm, and sites in the eastern marsh comprised 35 (34%) of the 102 data points. However, eastern marsh sites made up 50% of the data points with annual pond water SC values less than 10 mS/cm, and only 16% of the sites over 15 mS/cm. This indicates that eastern marsh sites do tend to have lower pond water SC than those in the western marsh.

3. Relationship between Applied Water and Pond Water Specific Conductance
Generally, the influence of applied water SC on pond water SC varies with the period in the water management cycle. During flood up (September and October), pond water SC is often independent of applied water SC because salts that accumulated on or near the surface of the soil during the summer are entering the pond water, causing pond water SC to be substantially higher than the applied water SC.

During December, January, and February, most ownerships had pond water SC that was quite close to the applied water SC. Effective circulation aids in keeping pond water SC close to that of the applied water because there is continual removal of the more saline pond water and introduction of lower SC channel water. During the leaching cycles, usually from February to May, as the pond is quickly drained and flooded, pond water SC generally corresponds closely to applied water SC. Most ponds showed large increases in pond water SC during the final drain (usually after March), because during final drawdown no water is being applied to the pond, and the remaining water is picking up salts and evaporating and concentrating those salts.

In examining the long term graphs of monthly pond and applied water SC for the monitored sites, (Figures IV-3 to IV-14) it is apparent that at most sites, pond water was rarely more than 5 mS/cm greater than applied water, except during and after final drawdown, and less regularly during flood up. This was true at Morrow Island (Fig IV-3), Island Club (Fig IV-7), Grizzly King (Fig IV-9), Sprig (Fig IV-10), Grizzly Island (Fig IV-11), and West Family (Fig IV-13). Pond water values from Tule Belle (Fig IV-4), Joice Island (Fig IV-6), Gum Tree (Fig IV-8), and Mallard (Fig IV-12) were usually 0-10 mS/cm greater than applied water. Pond water at Teal (Fig IV-5) and Goodyear (Fig IV-14) was usually more than 10 mS/cm greater than applied water.

The percent difference between the applied water SC January-June average and the pond water SC January-June average ([pond water SC – applied water SC/applied water SC]x100) was computed to evaluate changes in the pond water SC with respect to applied water (Figures IV-15 to IV-26). In general, there did not appear to be an increase in pond water SC relative to applied water SC over the study period. The percent difference at most monitored ownerships fluctuated over the study period, and was generally within 200%. One exception occurred during water year 1993, when all monitored ownerships with data for that year showed a significant increase in percent difference. Water year 1993 had above normal precipitation, resulting in significantly lower channel water salinities, as seen in Table II-3. Pond water salinities also decreased (Table IV-1), but the magnitude was much smaller; consequently, percent differences ranged from approximately 300% to over 1,000%. A similar pattern was seen in 1995, which was a wet year following a critical year.

These results show that over a single year, the application of lower SC water did not significantly lower pond water SC. If the application of lower SC water exerted a significant influence on pond water SC, the percent difference between applied and pond water would be expected to remain within the general value of 200%. Given that the percent difference increased up to 1000%, approximately 5 times the typical percent difference, it appears that applied water SC may not be the dominant factor affecting short-term pond water SC. It is interesting to note that the monitored ownership with the lowest increase in percent difference in 1993 (300%), was West Family (Fig IV-25). West Family was one of the monitored ownerships that intensively managed water, suggesting that management may play a greater role than applied water SC in the short-term effects on pond water SC.

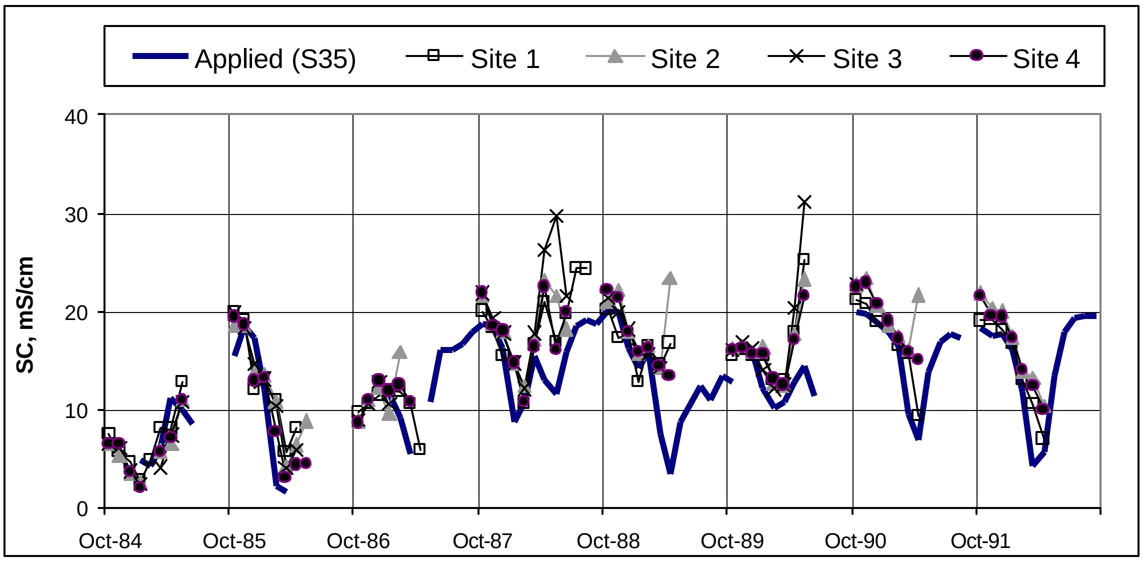


Figure IV-3. Monthly applied (channel) and pond water SC at Morrow Island WY85-92.

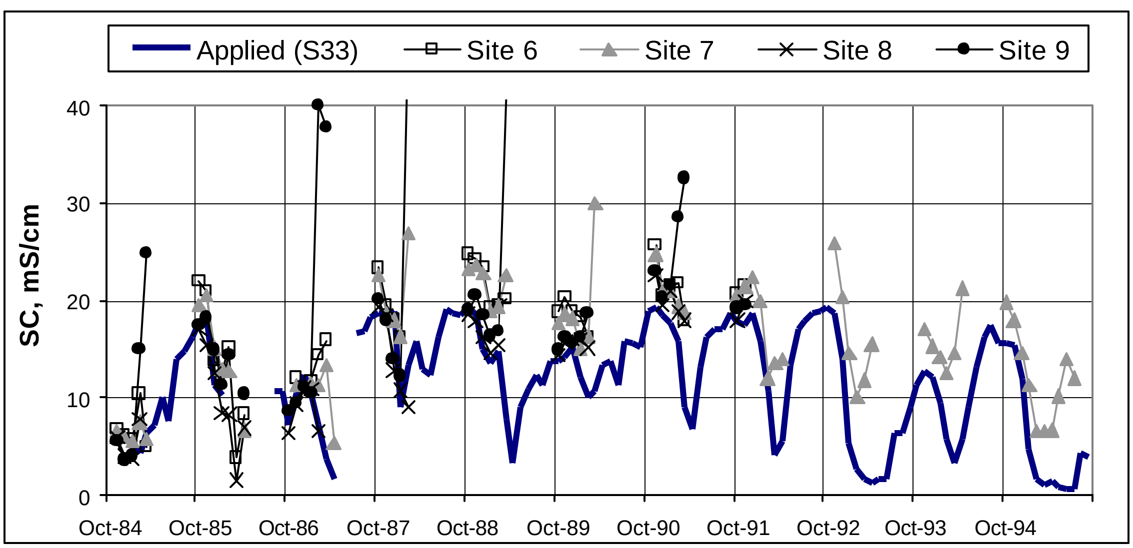


Figure IV-4. Monthly applied and pond water SC at Tule Belle WY85-95.

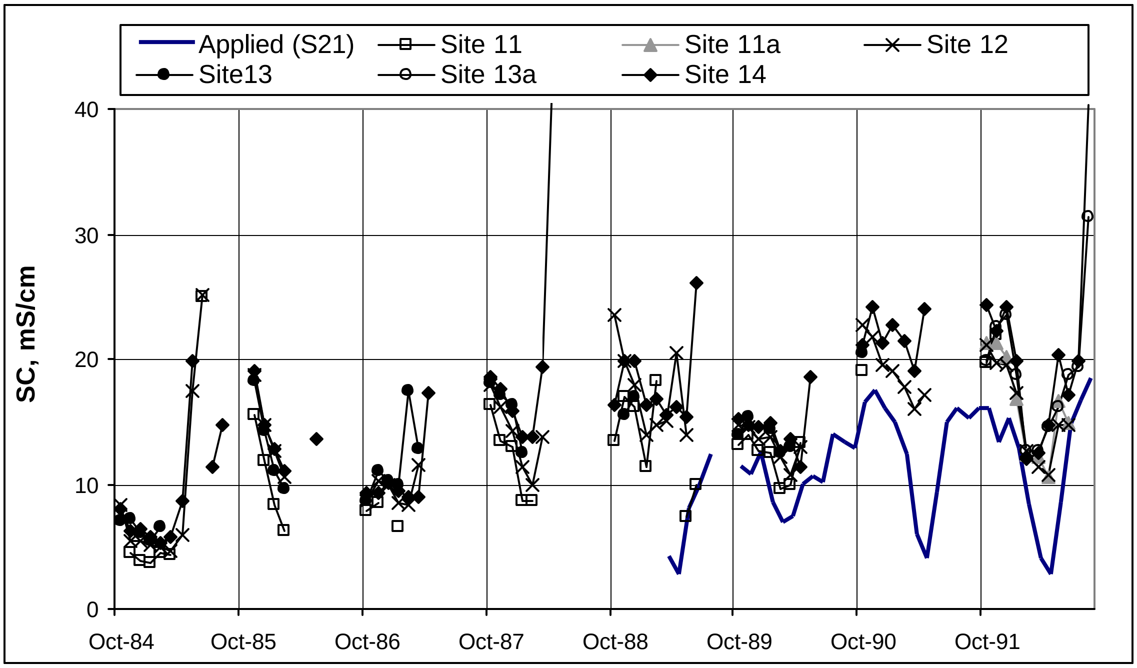


Figure IV-5. Monthly applied and pond water SC at Teal WY85-92.

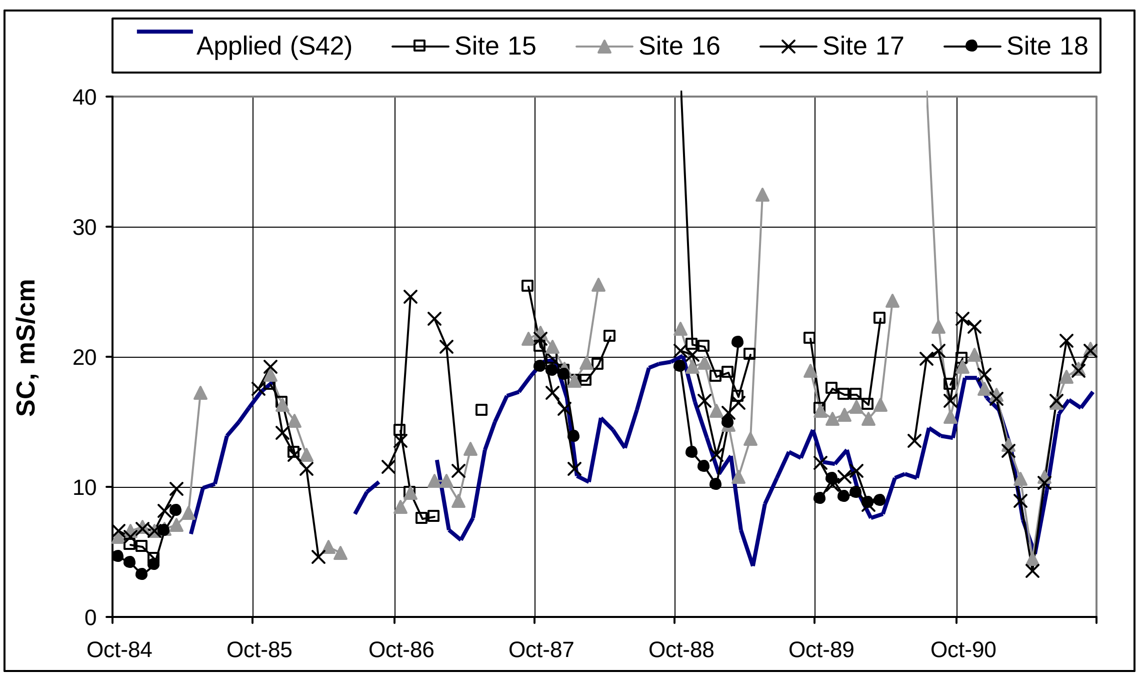


Figure IV-6. Monthly applied and pond water SC at Joice Island WY85-91.

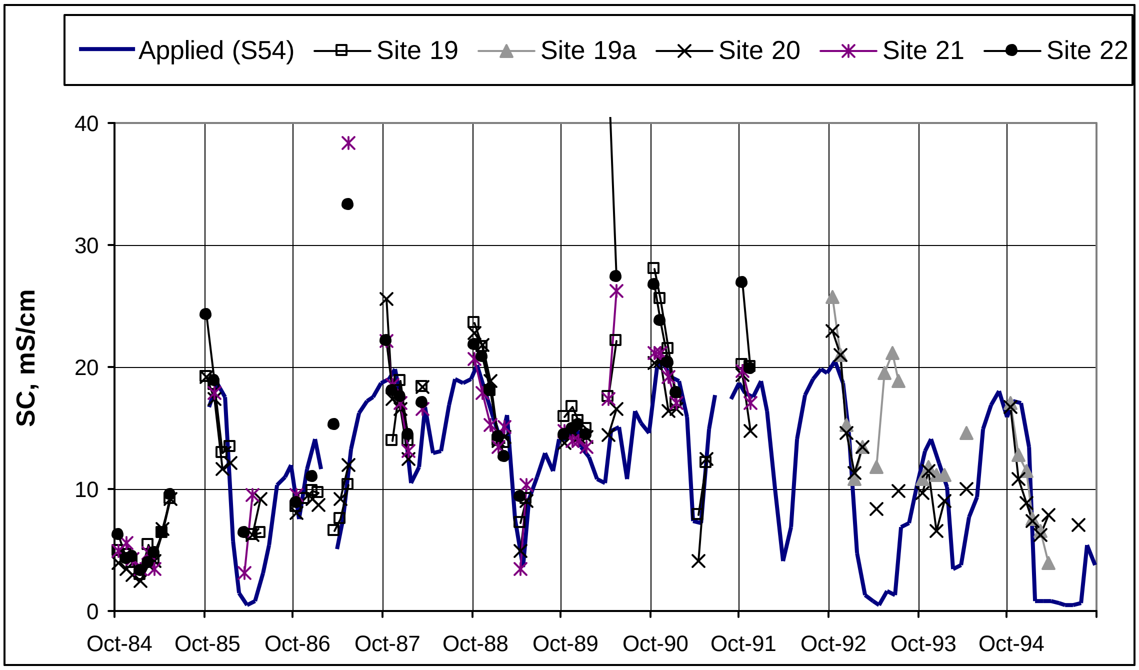


Figure IV-7. Monthly applied and pond water SC at Island Club WY85-95.

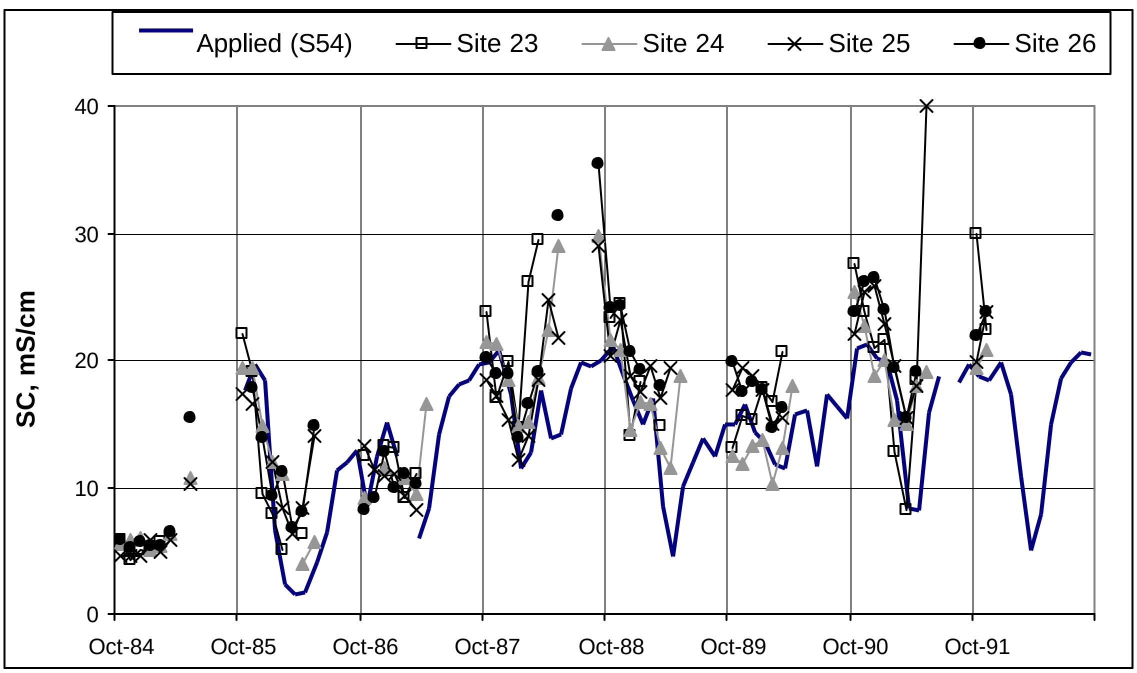


Figure IV-8. Monthly applied and pond water SC at Gum Tree WY85-92.

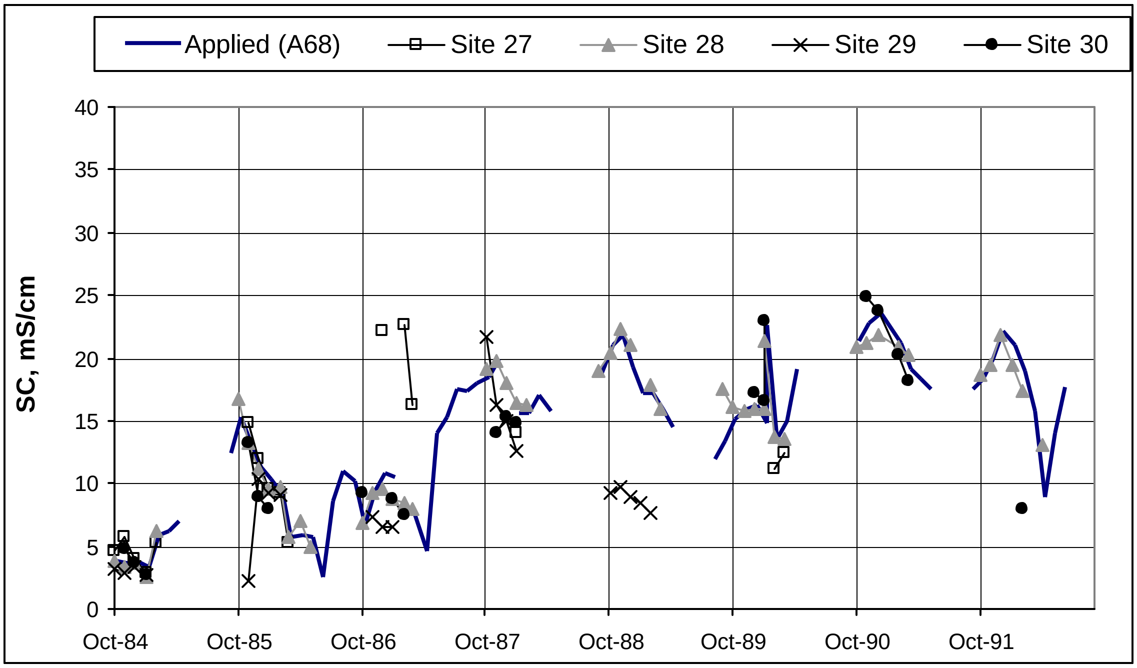


Figure IV-9. Monthly applied and pond water SC at Grizzly King WY85-92.

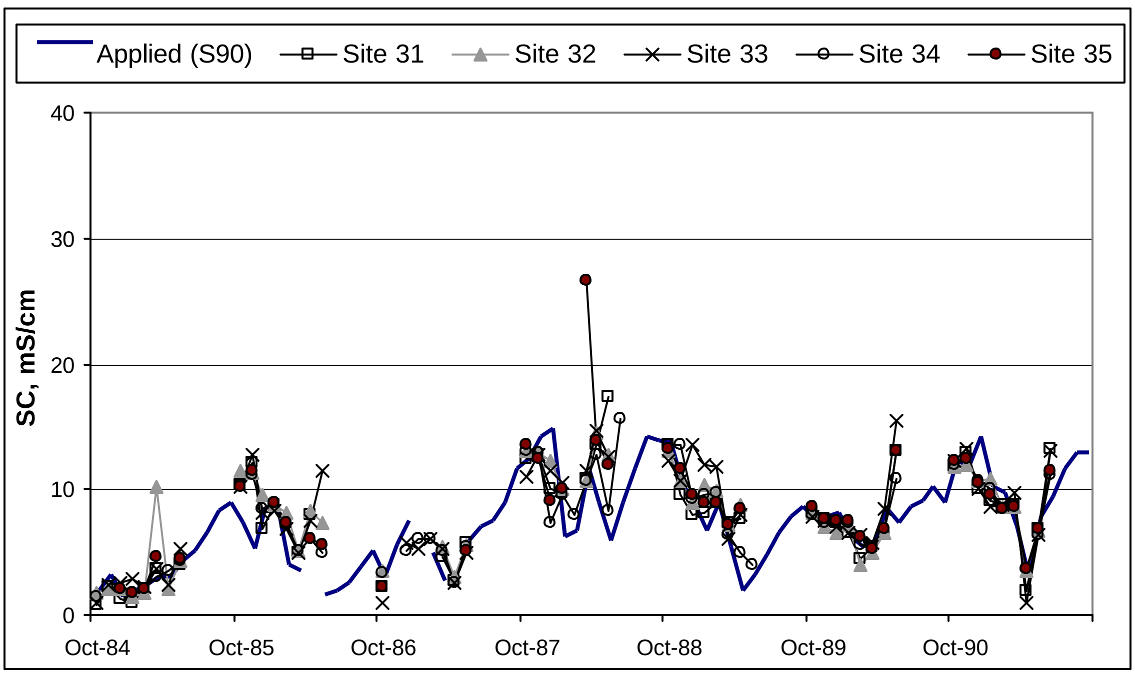


Figure IV-10. Monthly applied and pond water SC at Sprig, WY85-91.

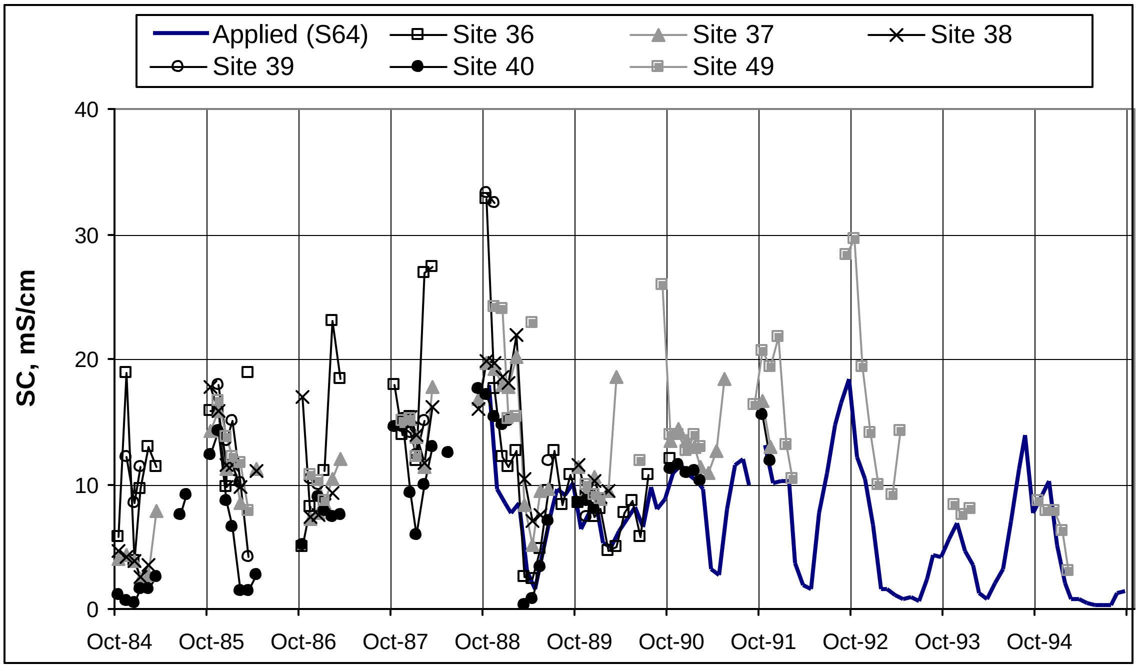


Figure IV-11. Monthly applied and pond water SC at Grizzly Island, WY85-95.

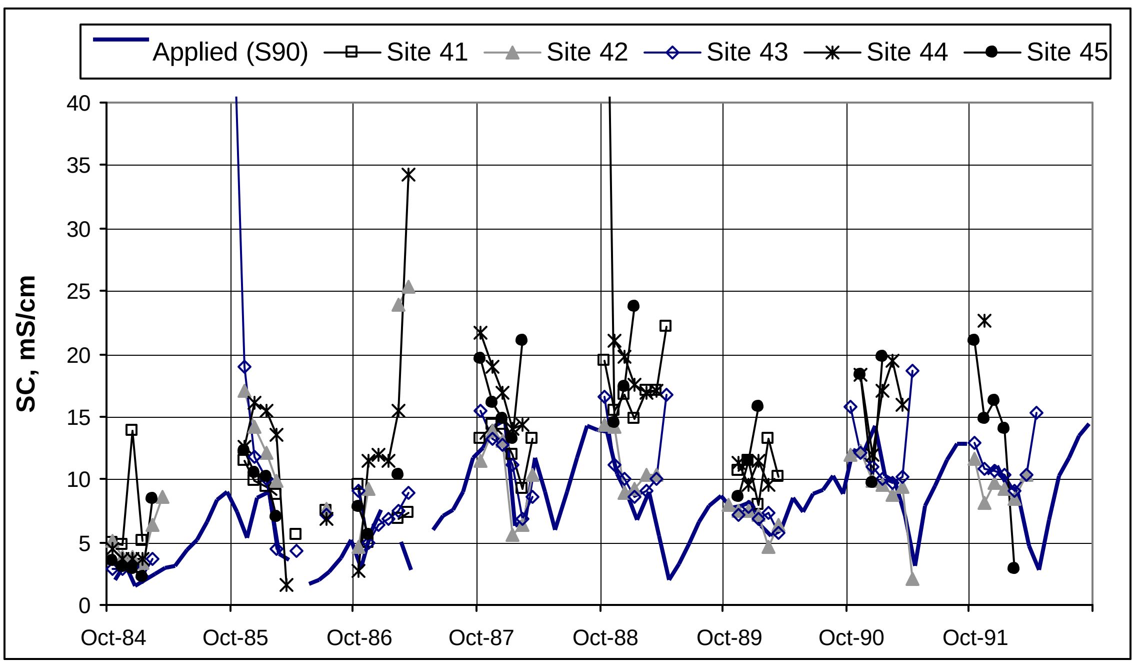


Figure IV-12. Monthly applied and pond water SC at Mallard, WY85-92.

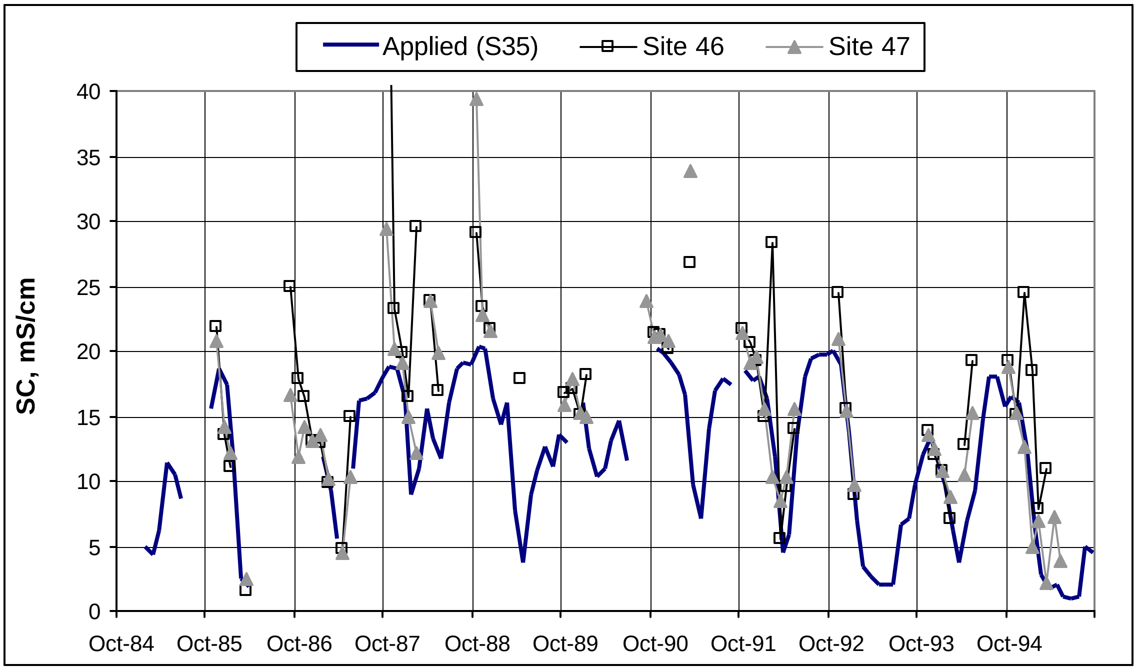


Figure IV-13. Applied and Pond Water SC at West Family, Water Years 1986-1995.

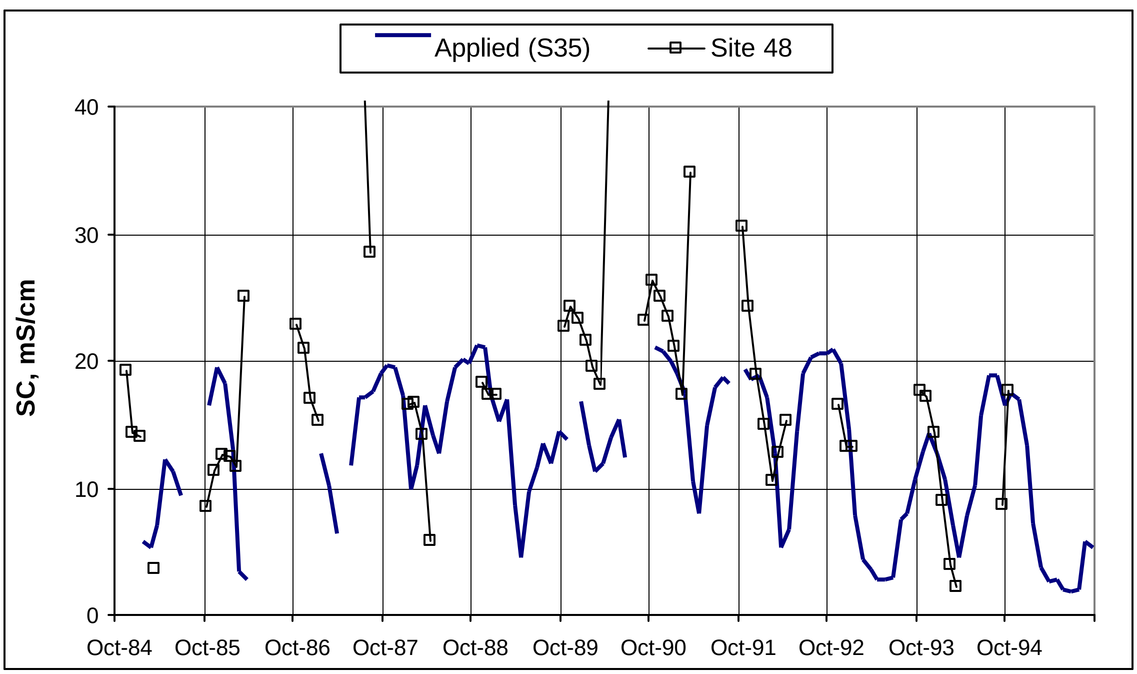


Figure IV-14. Monthly applied and pond SC at Goodyear, WY85-95.

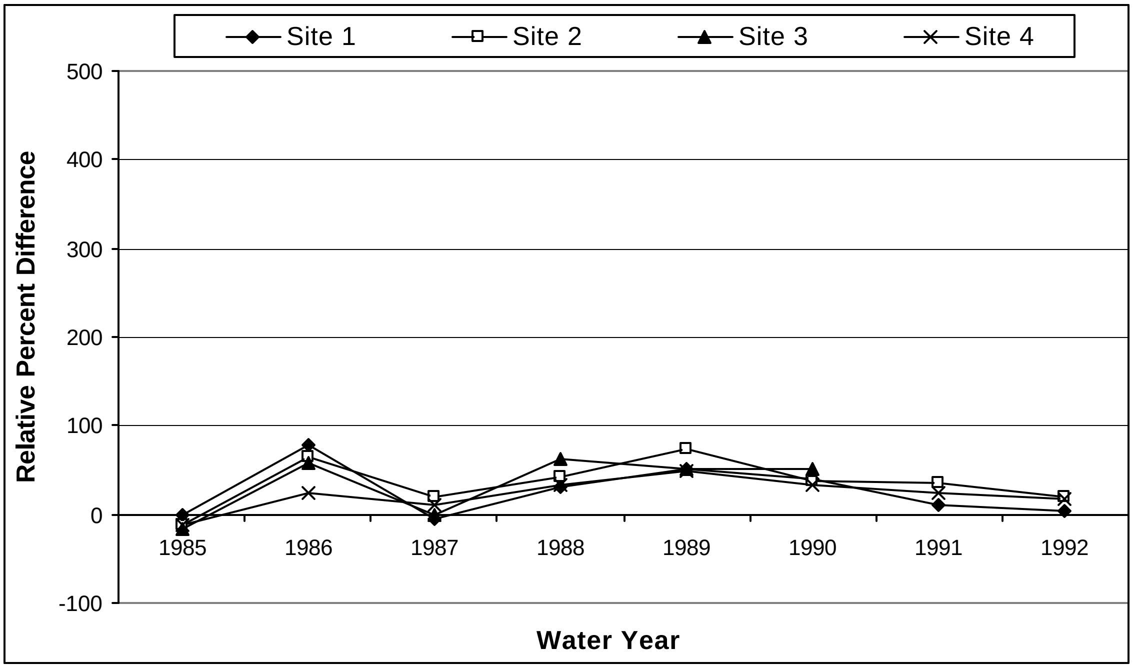
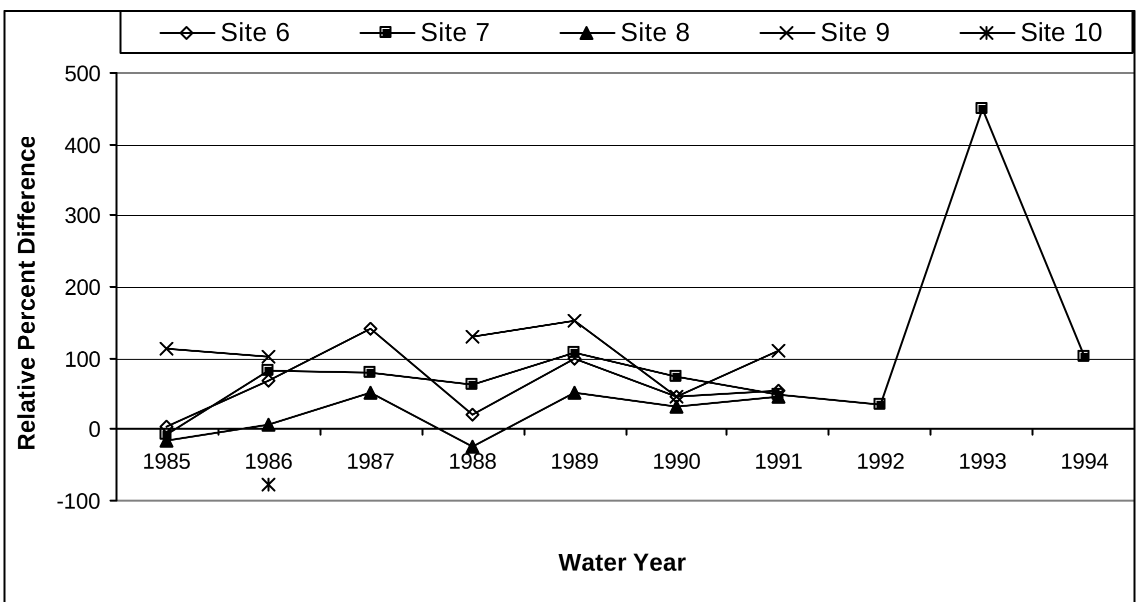


Figure IV-15. Relative percent difference between pond water SC and applied water (S35) at Morrow Island (January–June).



Note: WY 1987 data point for site 9 removed because the pond water data was available only for the period after drawdown.

Figure IV-16. Relative percent difference between pond water SC and applied water (S33) at Tule Belle (January - June).

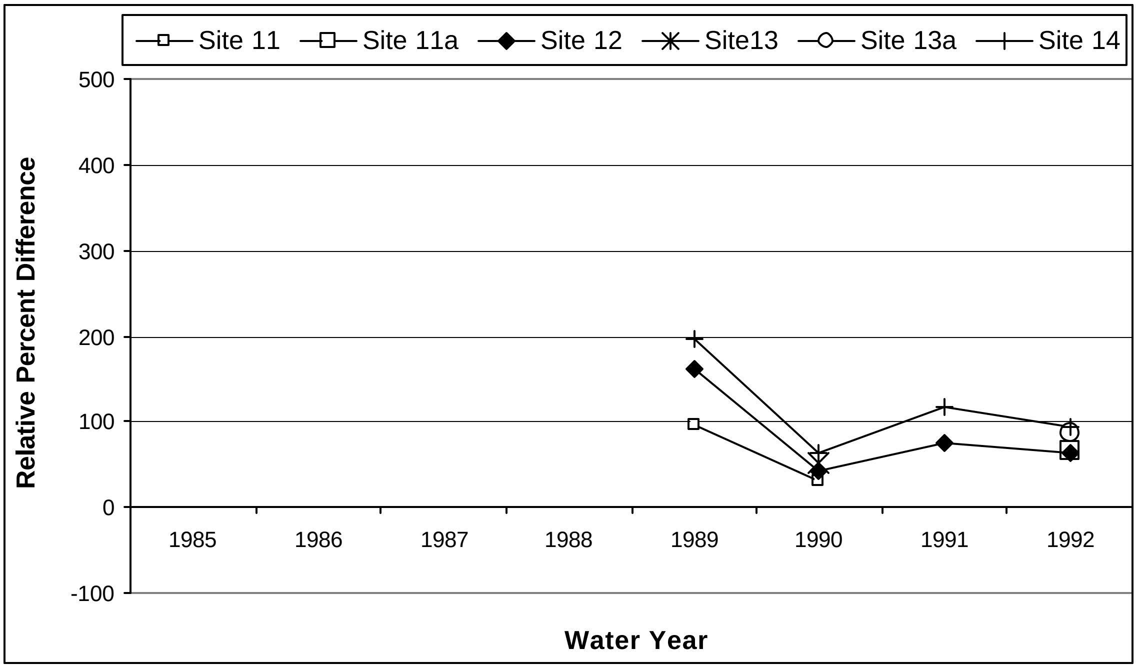


Figure IV-17. Relative percent difference between pond water SC and applied water (S21) at Teal (January - June).

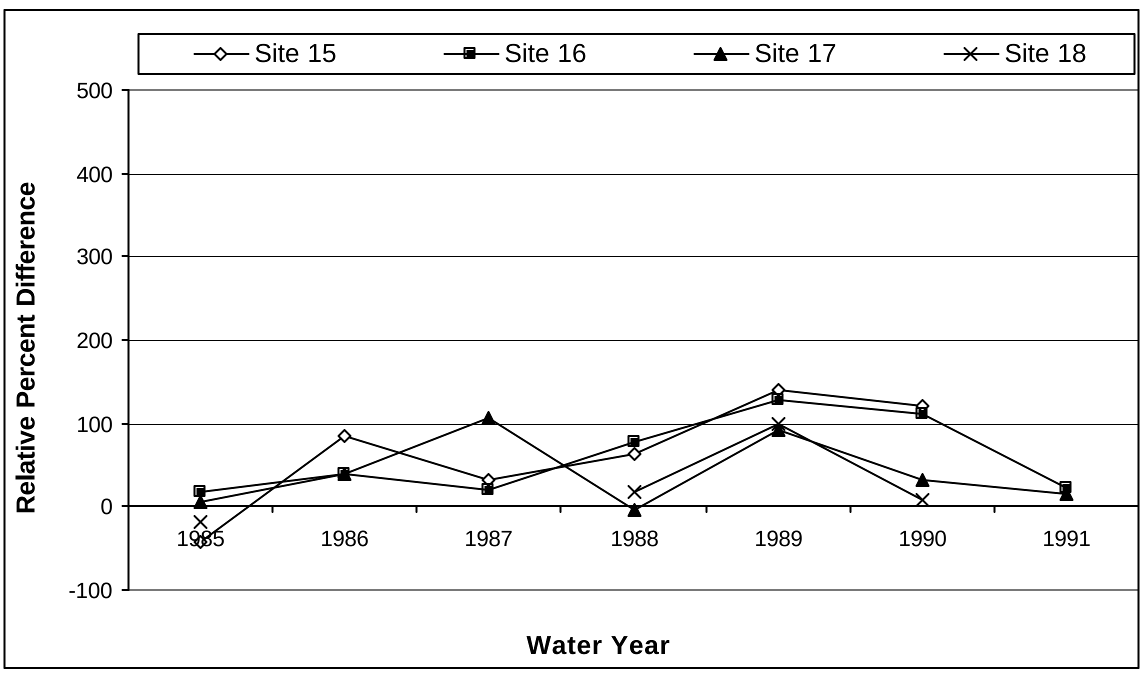


Figure IV-18. Relative percent difference between pond water SC and applied water (S42) at Joice Island (January - June).

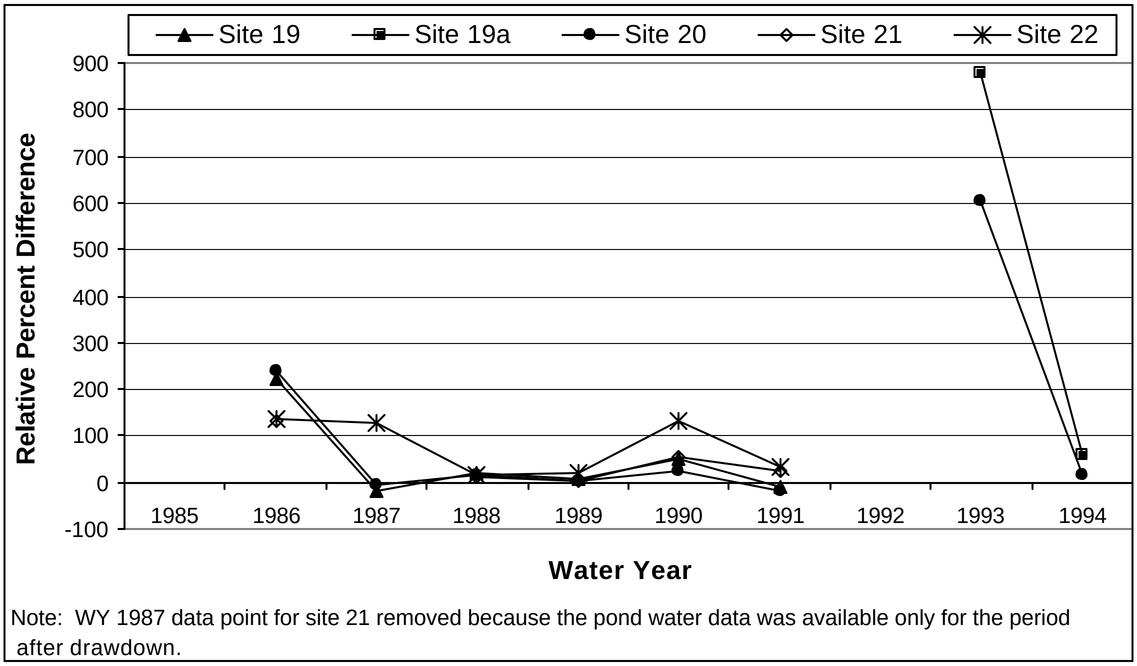


Figure IV-19. Relative percent difference between pond water SC and applied water (S54) at Island Club (January - June).

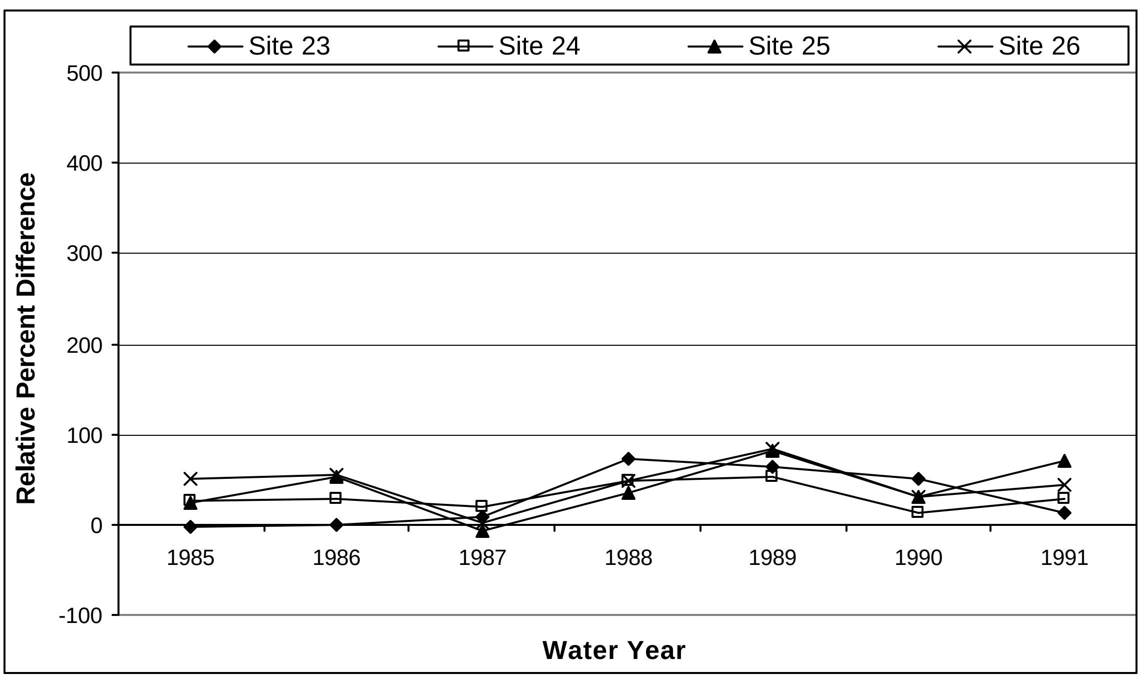


Figure IV-20. Relative percent difference between pond water SC and applied water (S54) at Gum Tree (January - June).

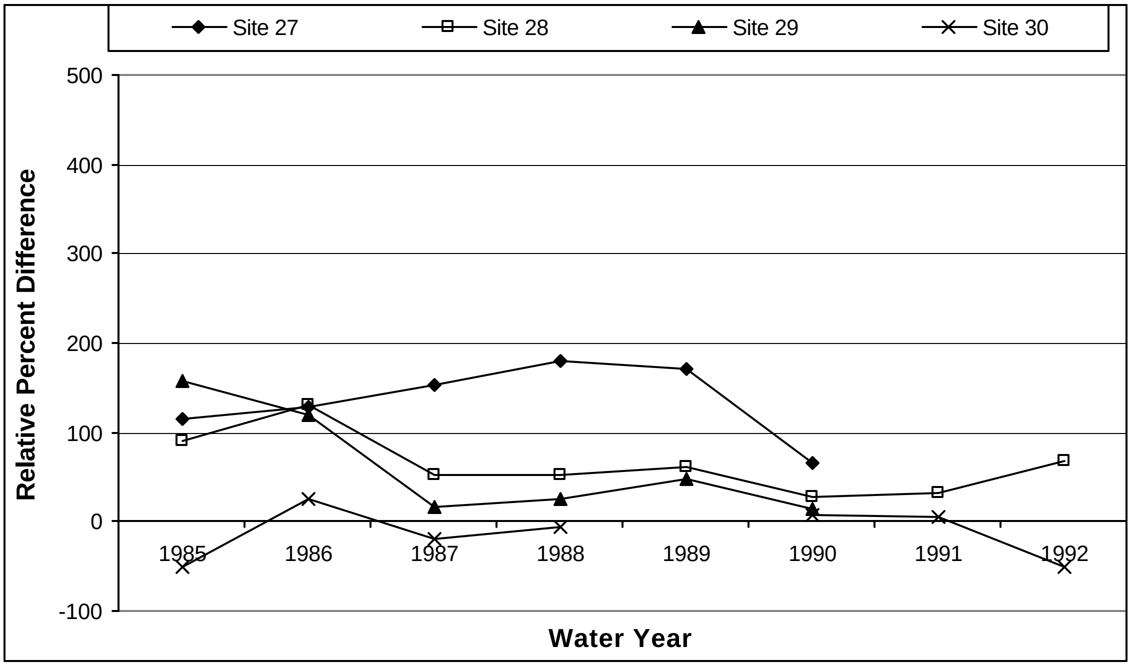


Figure IV-21. Relative percent difference between pond water SC and applied water (A68) at Grizzly King (January - June).

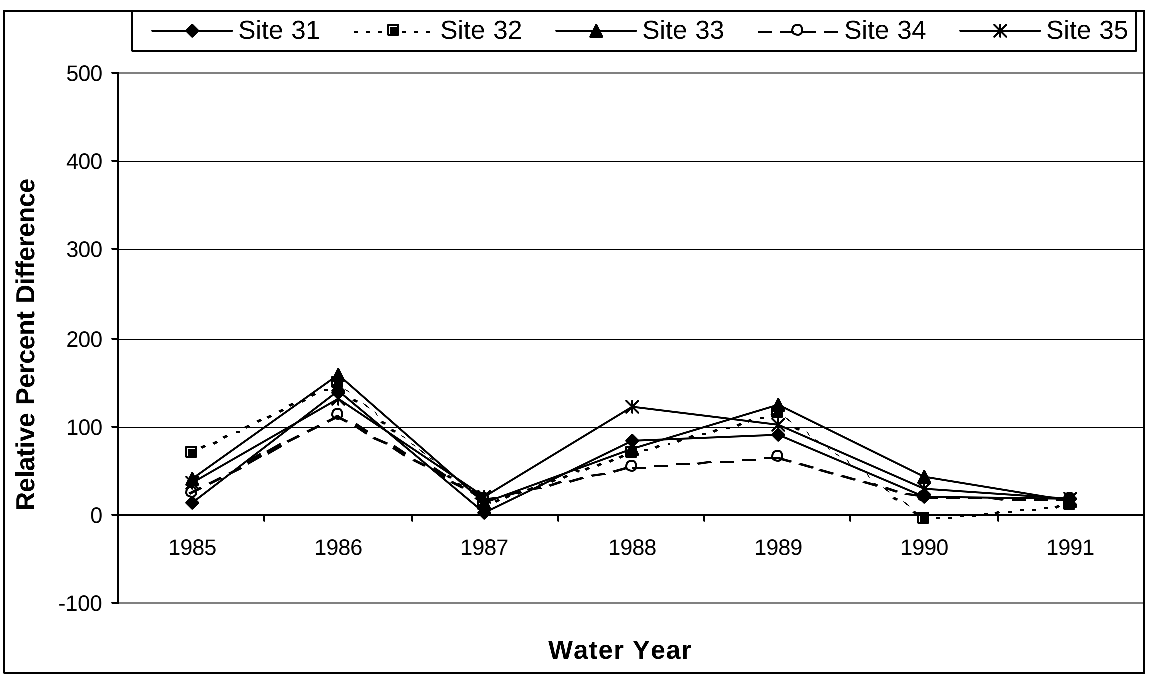


Figure IV-22. Relative percent difference between pond water SC and applied water (A90) at Sprig (January - June).

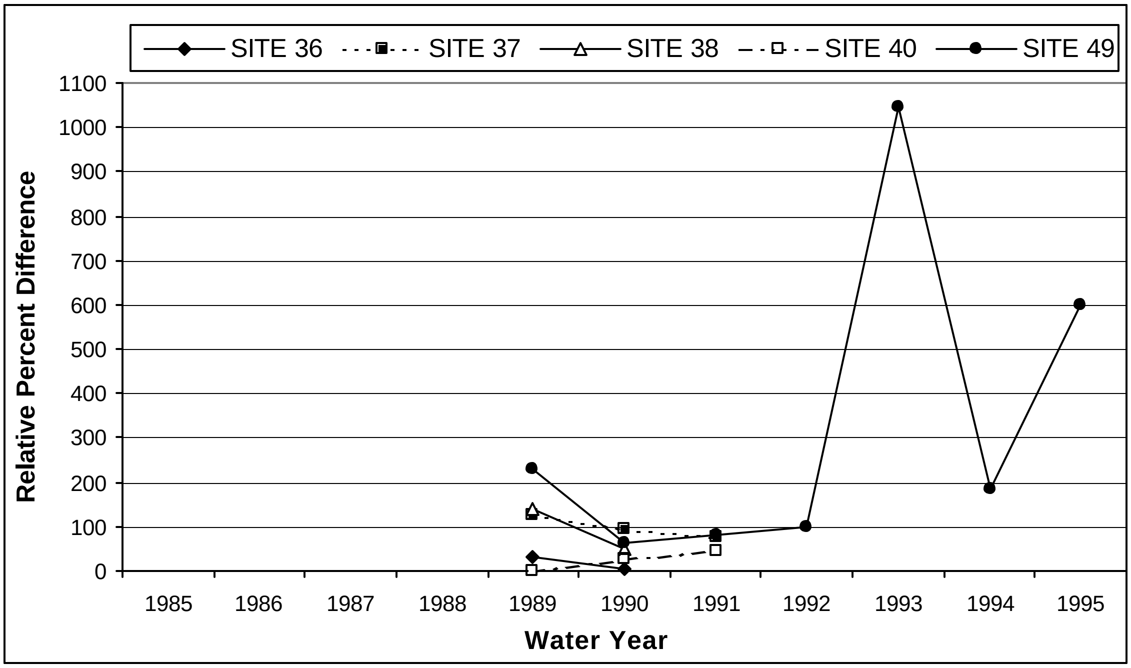


Figure IV-23. Relative percent difference between pond water SC and applied water (S64) at Grizzly Island (January - June).

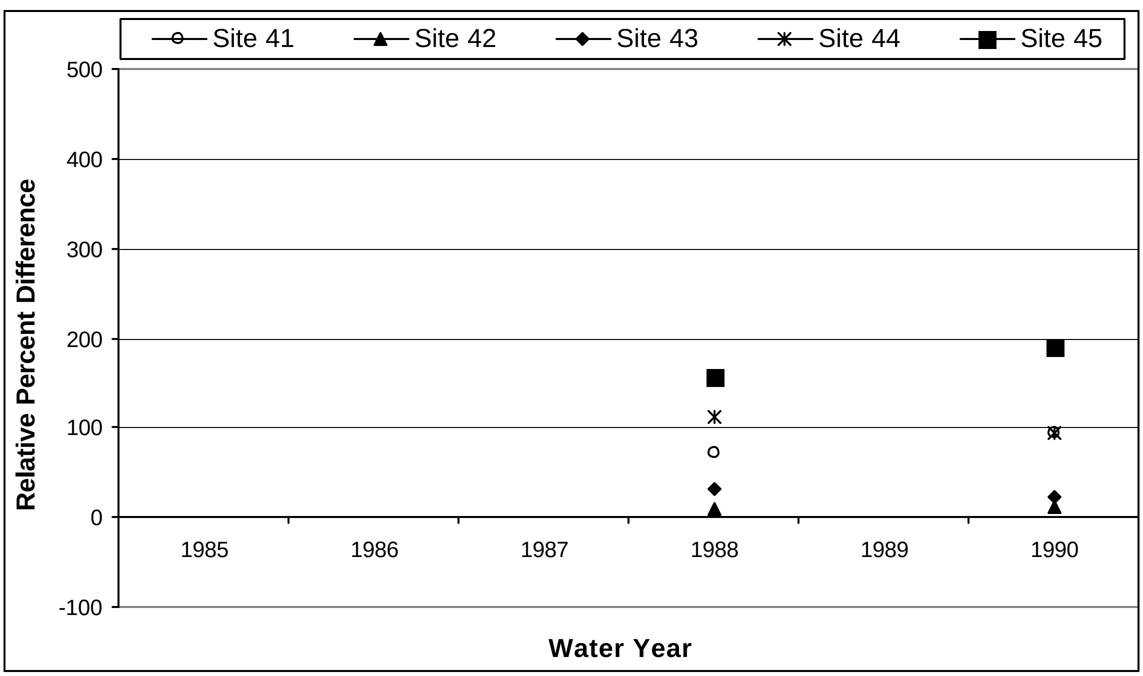


Figure IV-24. Relative percent difference between pond water SC and applied water (S90) at Mallard (January - June).

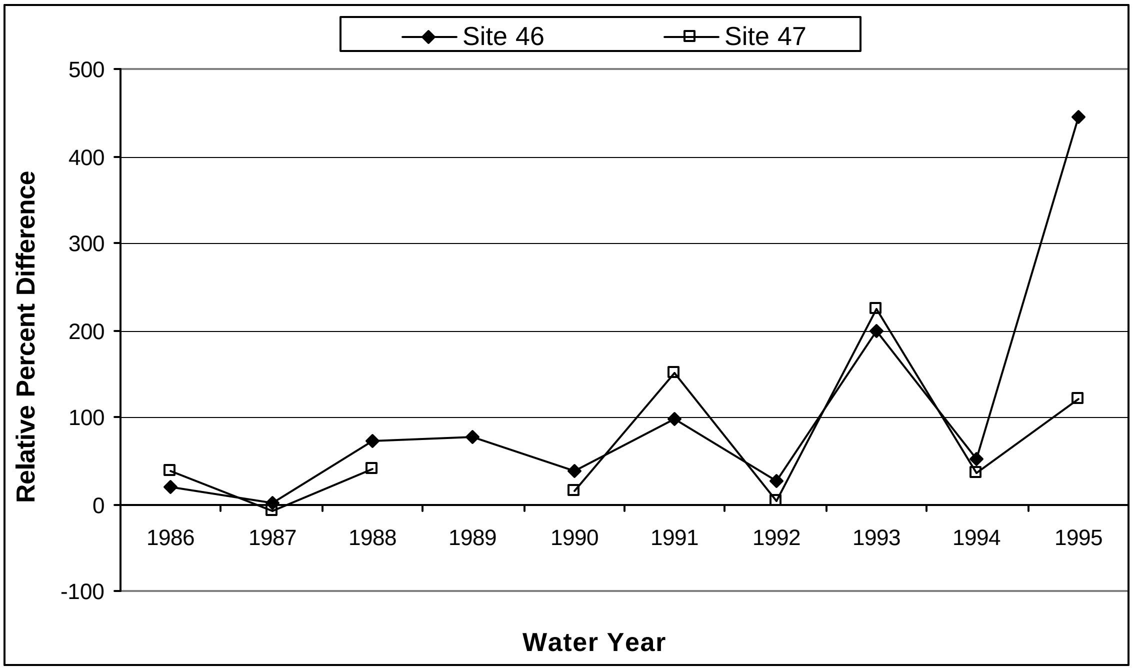


Figure IV-25. Relative percent difference between pond water SC and applied water (S35) at West Family (January - June).

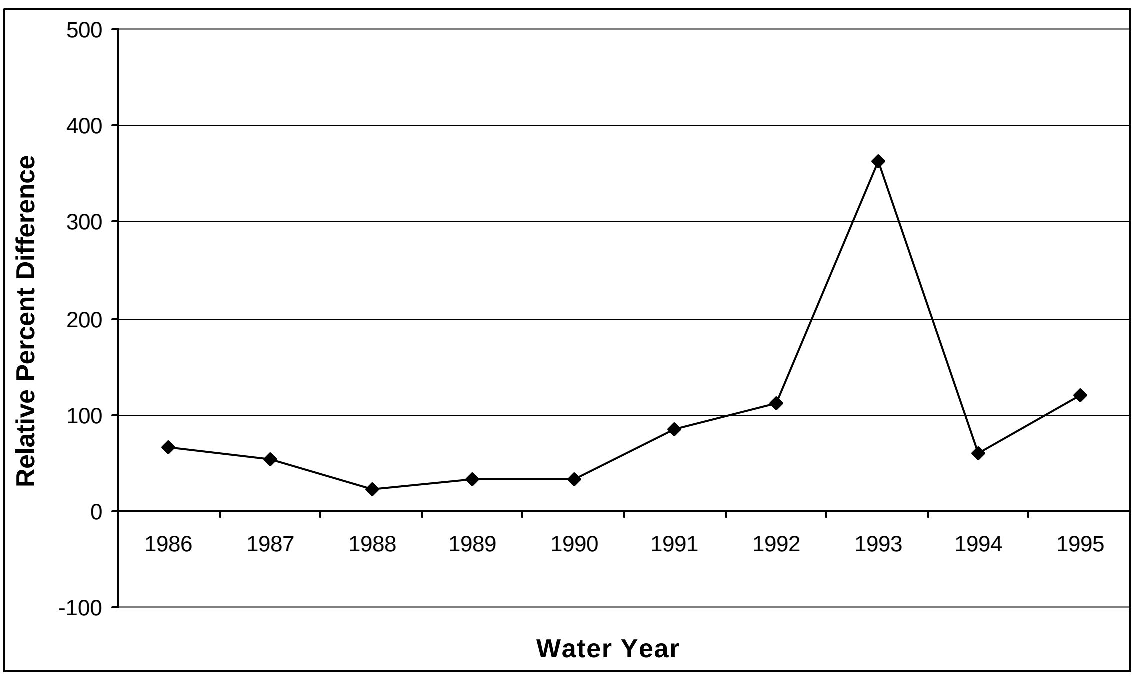


Figure IV-26. Relative percent difference between pond water SC and applied water (S35) at Goodyear (January - June).

4. Within-ownership Variation in Pond Water Specific Conductance

Variation of pond water SC within a pond is due primarily to topography within the pond and the effects of water management. If a pond has intakes from different sources, the SC may vary across the pond relative to the proximity to the different water intakes. Sometimes a pond has a freshwater influence from local runoff, and sites in the path of runoff may record lower pond water SC as a result (site 8 at Tule Belle, for example).

Management may also affect the variation in water SC within a pond. Circulation can have significant effects on pond water SC. Theoretically, when a pond is well circulated, the SC of the water should be fairly uniform throughout the pond at any given time. Thus, poorly circulated ponds may display more variation among monitoring sites than well-circulated ponds.

Monthly pond water SC values were compared for the different sites at each monitored ownership. Tule Belle (Fig IV-7), Gum Tree (Fig IV-11), Grizzly King (Fig IV-12), and Mallard (Fig IV-15), had the greatest variation among monitoring sites, and pond water salinities among sites within a pond were rarely within 10 mS/cm,. Conversely, sites within a pond were almost always within 2 mS/cm of one another at Morrow Island (Fig IV-6), Teal (Fig IV-8), Island Club (Fig IV-10), Sprig (Fig IV-13), Grizzly Island pond 4A (Fig IV-14), and West Family (Fig IV-16).

As noted above, the pond water values at Morrow Island, Island Club, Grizzly King, Sprig, Grizzly Island, and West Family were usually very close to the SC values of the applied water. It is not surprising that pond water SC values at four of these ownerships also had consistently close pond water SC values within sites in each pond. Together, these are strong indications that Morrow Island, Island Club, Sprig and West Family were well-circulated ponds. However, these four ownerships did not have substantially lower annual average pond water SC than did the four ownerships with sites with more variable pond water SC values.

It must be noted that although the data suggest that some ownerships effectively circulated pond water and others did not, this is not a certainty. The monitoring program did not collect information from the managers about when water management actions were taken. The data collected are only suggestive, and do not indicate when circulation was done; therefore the effects of circulation on pond or soil water SC cannot be determined.

5. Pond (and Soil) Water pH

Pond water pH was measured throughout the monitoring period. Soil water pH was only measured from water year 1985 through 1987, so the data is presented here with the pond water data. Pond and soil water pH values are graphed in figures IV-27 through IV-38. Pond water pH was fairly stable at all sites, with values most commonly around 6 or 7. Soil water pH values were always more acidic than pond water pH, with values most commonly between 3 and 5. These acidic pH values are probably due to the presence of sulfuric acid which forms when organic matter in the soil reacts with sulfates in the channel water used to flood the ponds.

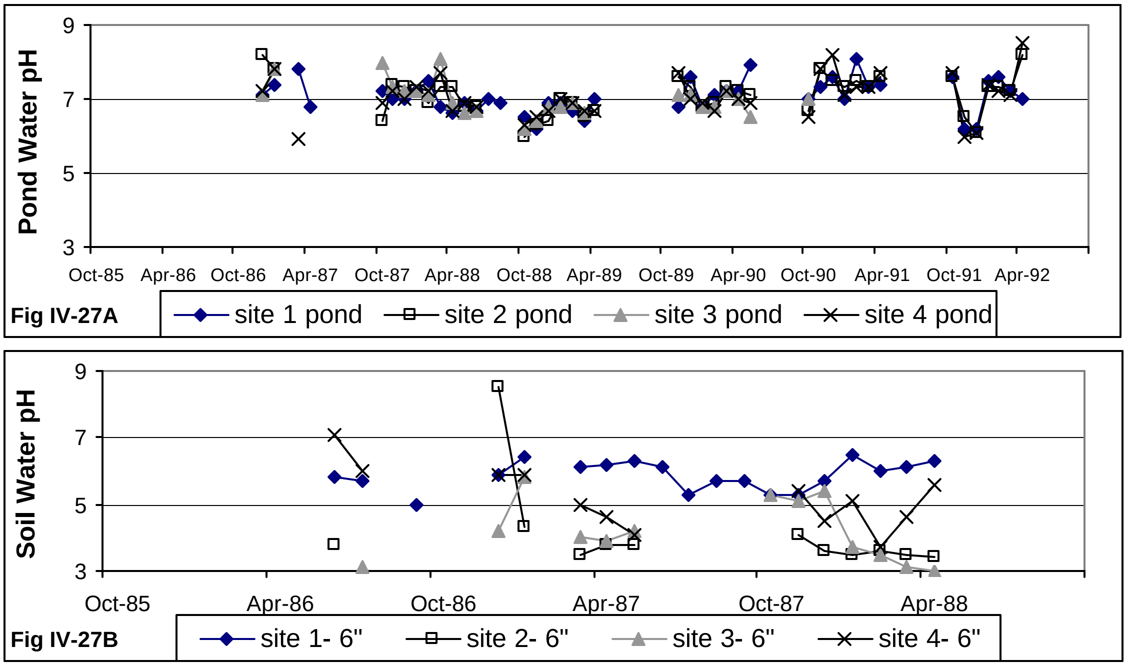
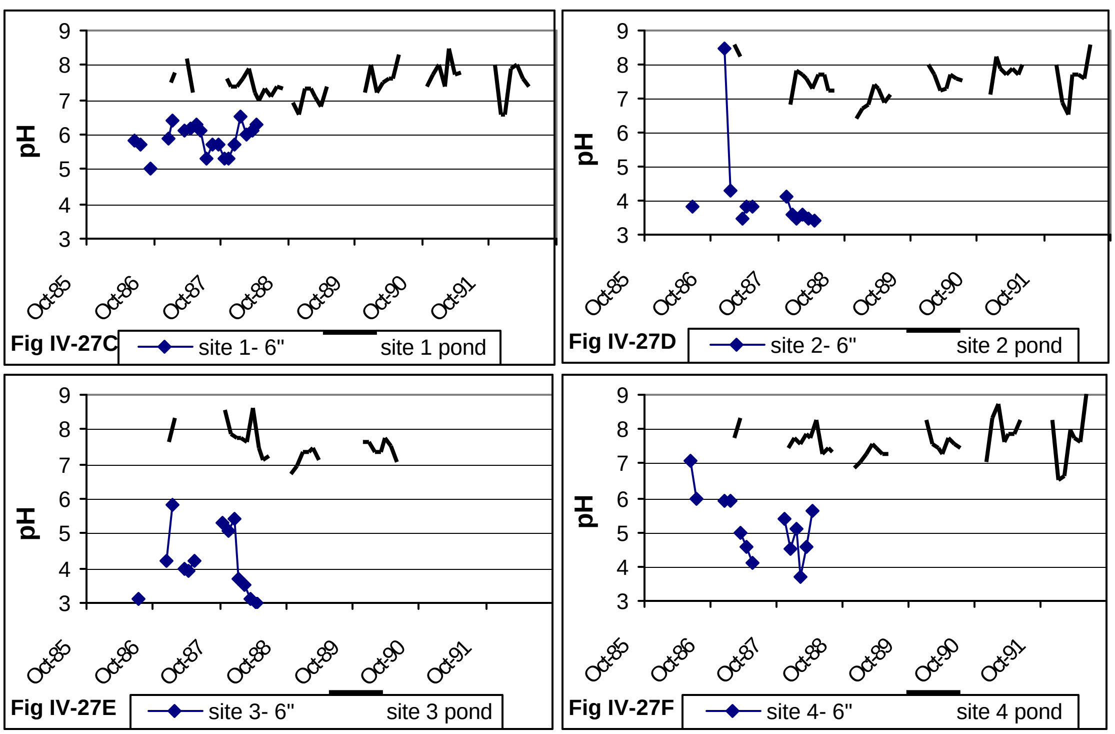


Figure IV-27A. Pond water pH values from sites 1-4 on Morrow Island Club.
Figure IV-27B. Soil water pH values from sites 1-4 on Morrow Island Club.



Figures IV-27C-F. Pond water and soil water pH values from Morrow Island Club sites 1-4, respectively.

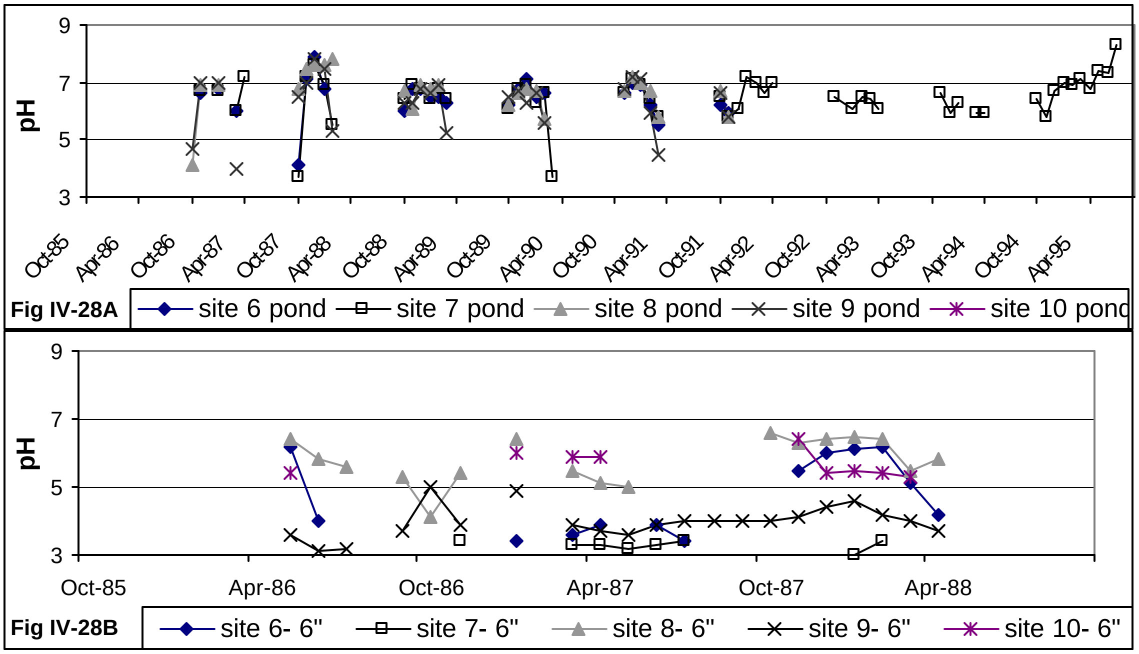
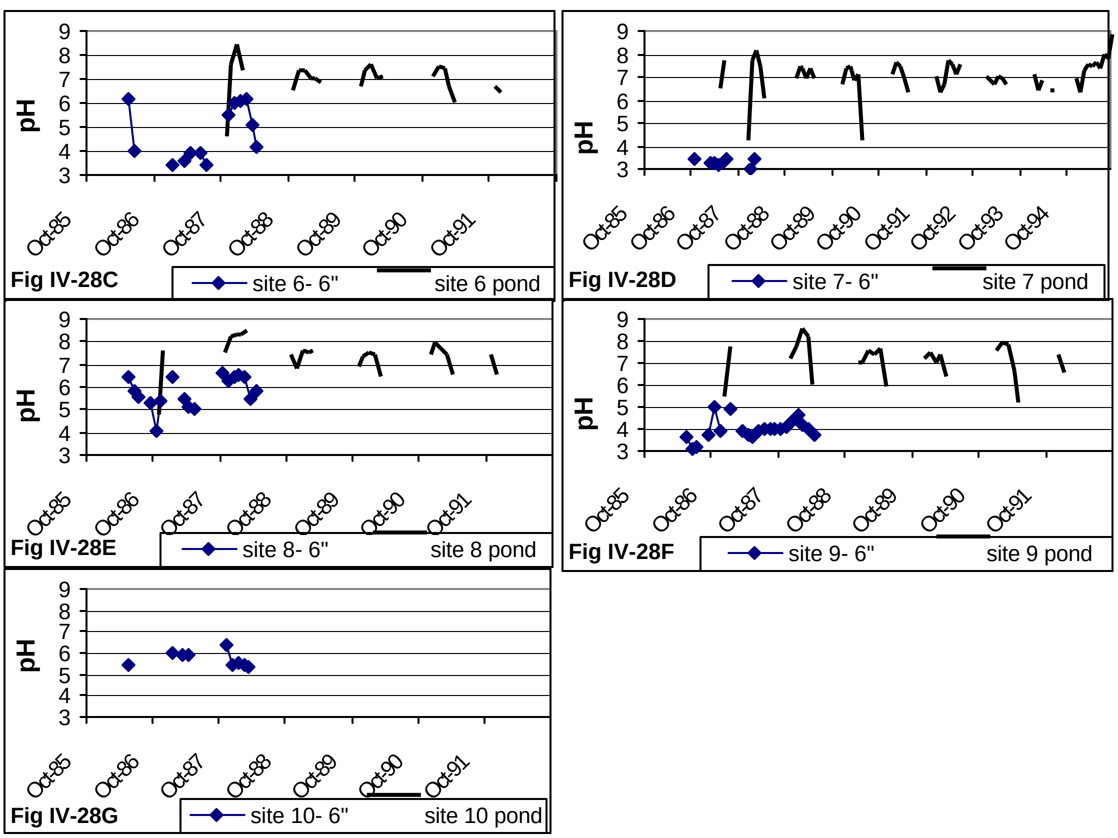


Figure IV-28A. Pond water pH values from sites 6-10 on Tule Belle Club.
Figure IV-28B. Soil water pH values from sites 6-10 on Tule Belle Club.



Figures IV-28C-G. Pond water and soil water pH values from Tule Belle Club sites 6-10, respectively.

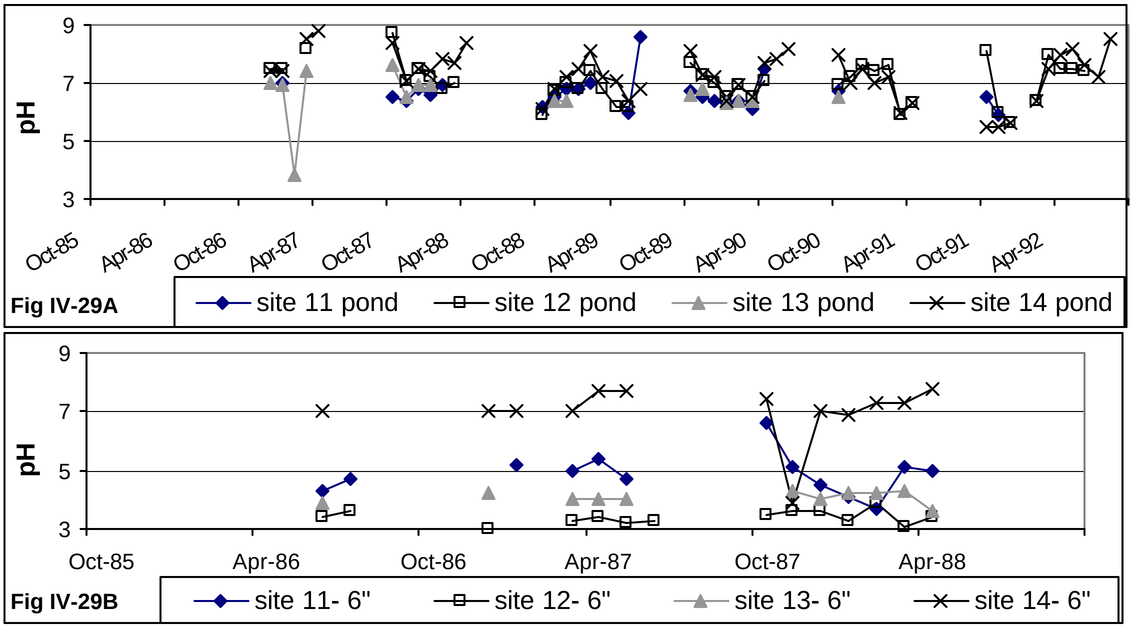


Figure IV-29A. Pond water pH values from sites 11-14 on Teal Club.
Figure IV-29B. Soil water pH values from sites 11-14 on Teal Club .

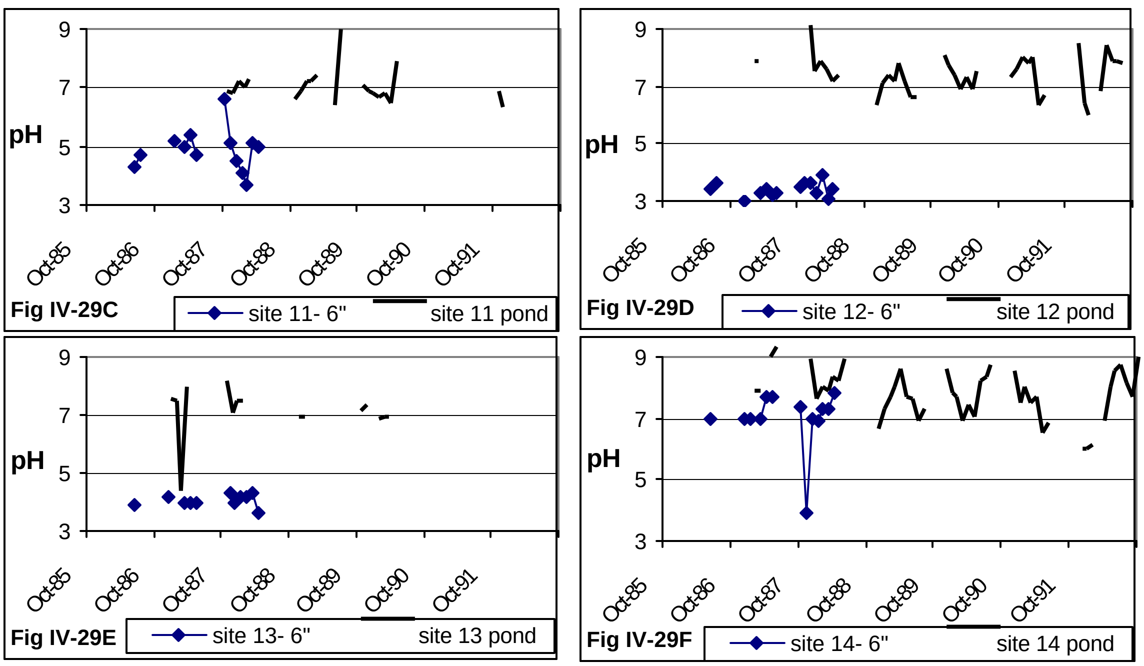


Figure IV-29C-F. Pond water and soil water pH values from Teal Club, sites 11-14.

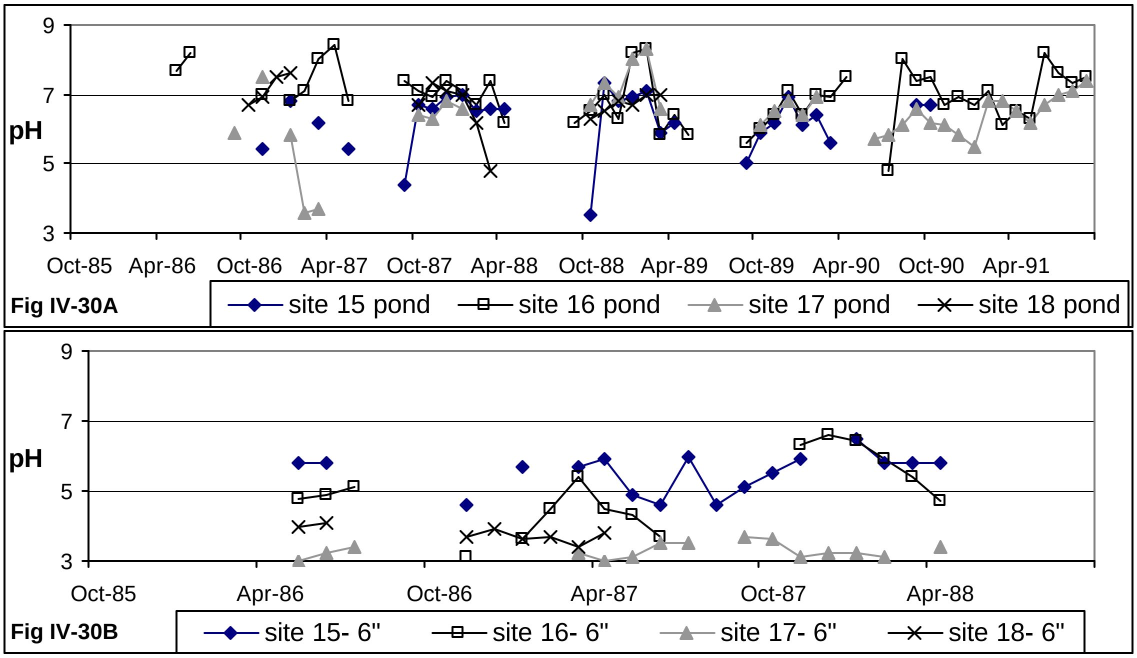


Figure IV-30A. Pond water pH values from sites 15-18 on Joice Island.
Figure IV-30B. Soil water pH values from sites 15-18 on Joice Island.

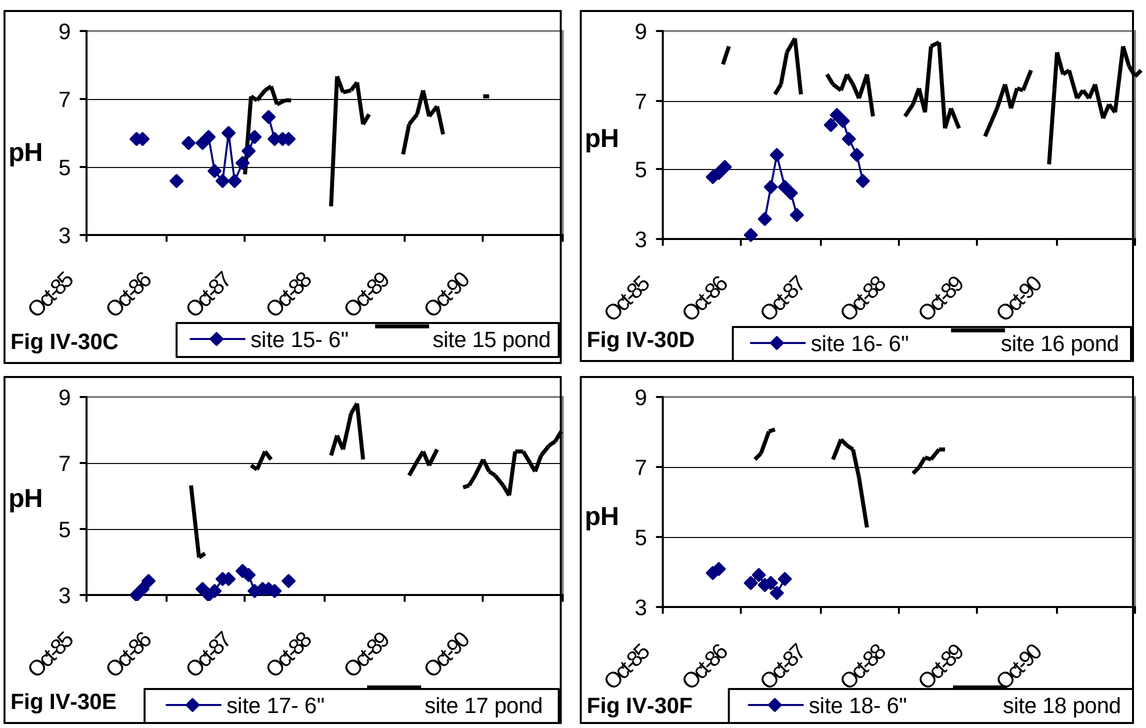
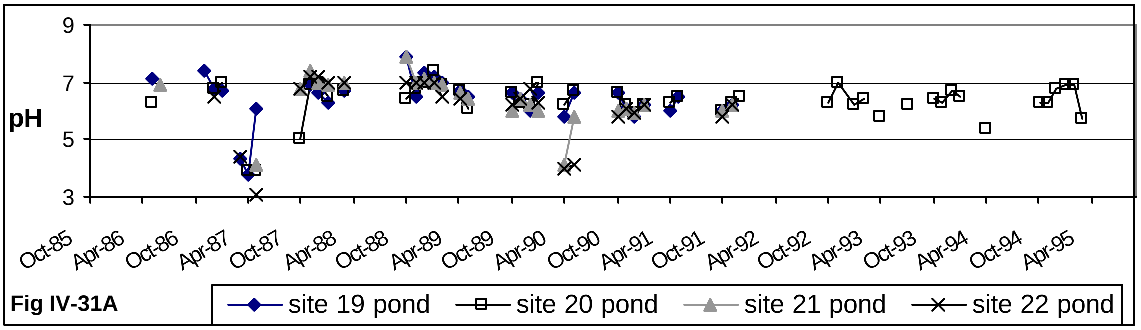


Figure IV-30C-F. Pond water and soil water pH values from Joice Island, sites 15-18.



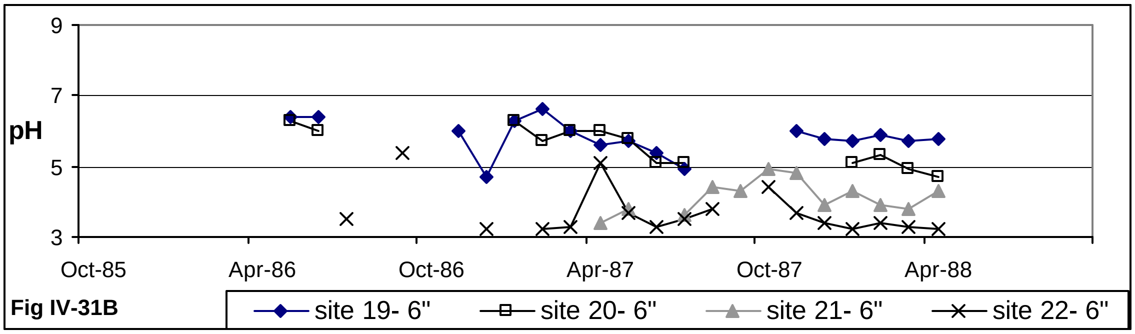


Figure IV-31A. Pond water pH values from sites 19-22 on Island Club.
Figure IV-31B. Soil water pH values from sites 19-22 on Island Club.

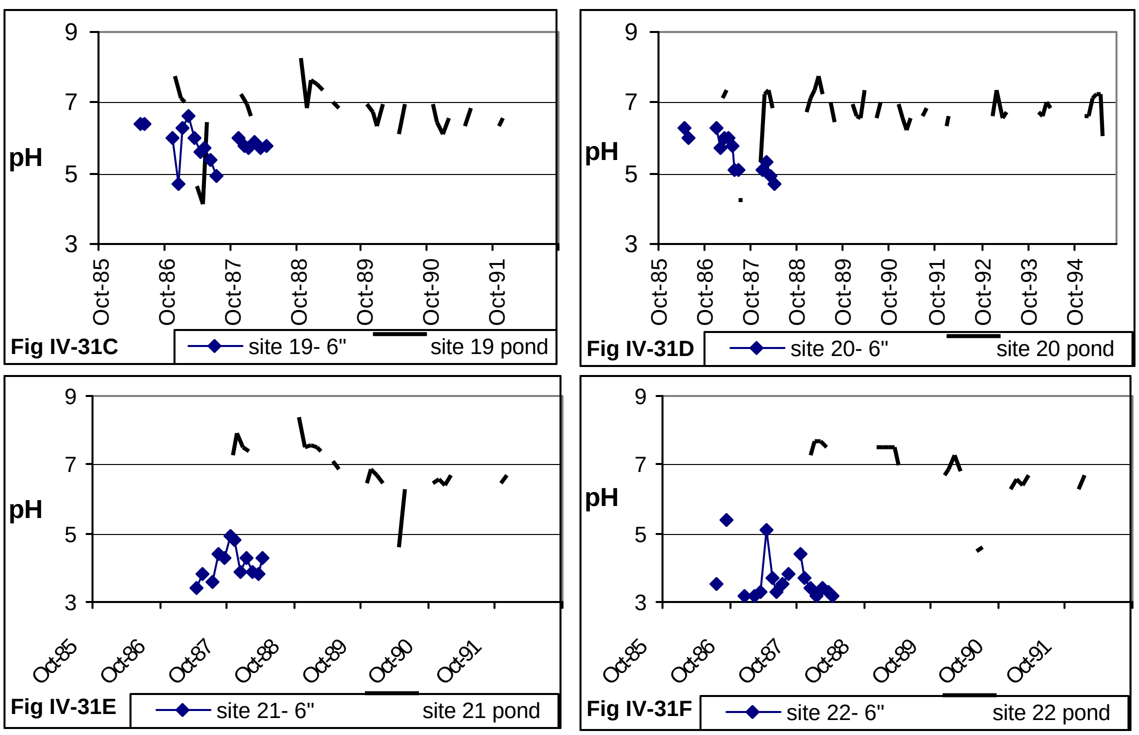
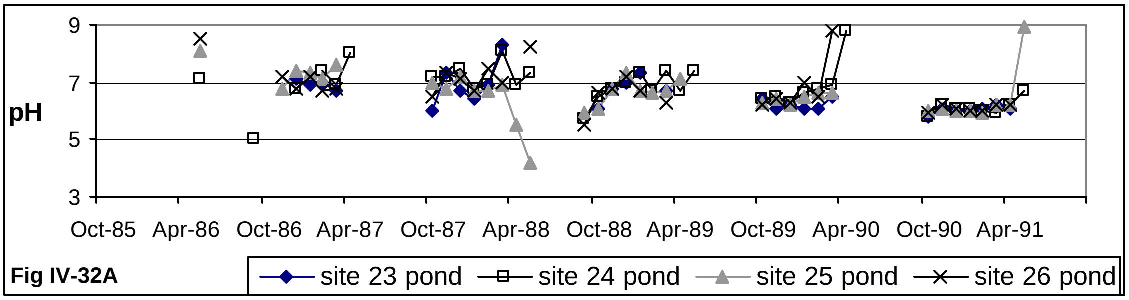


Figure IV-31C-F. Pond water and soil water pH values from Island Club sites 19-22.



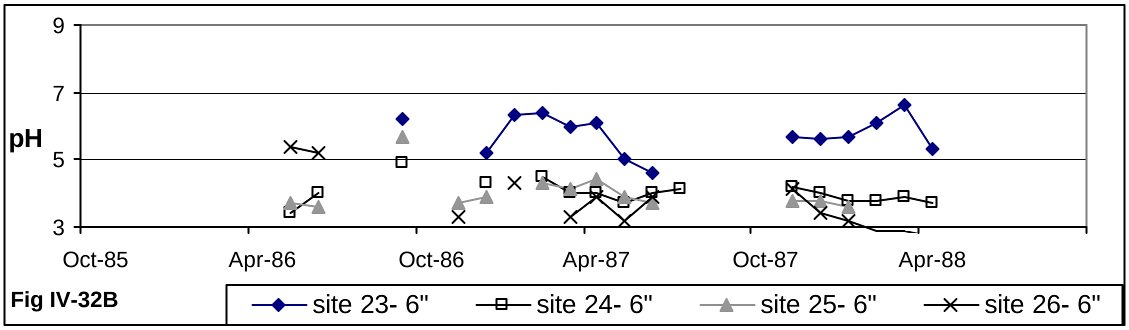


Figure IV-32A. Pond water pH values from sites 23-26 on Gum Tree.
Figure IV-32B. Soil water pH values from sites 23-26 on Gum Tree.

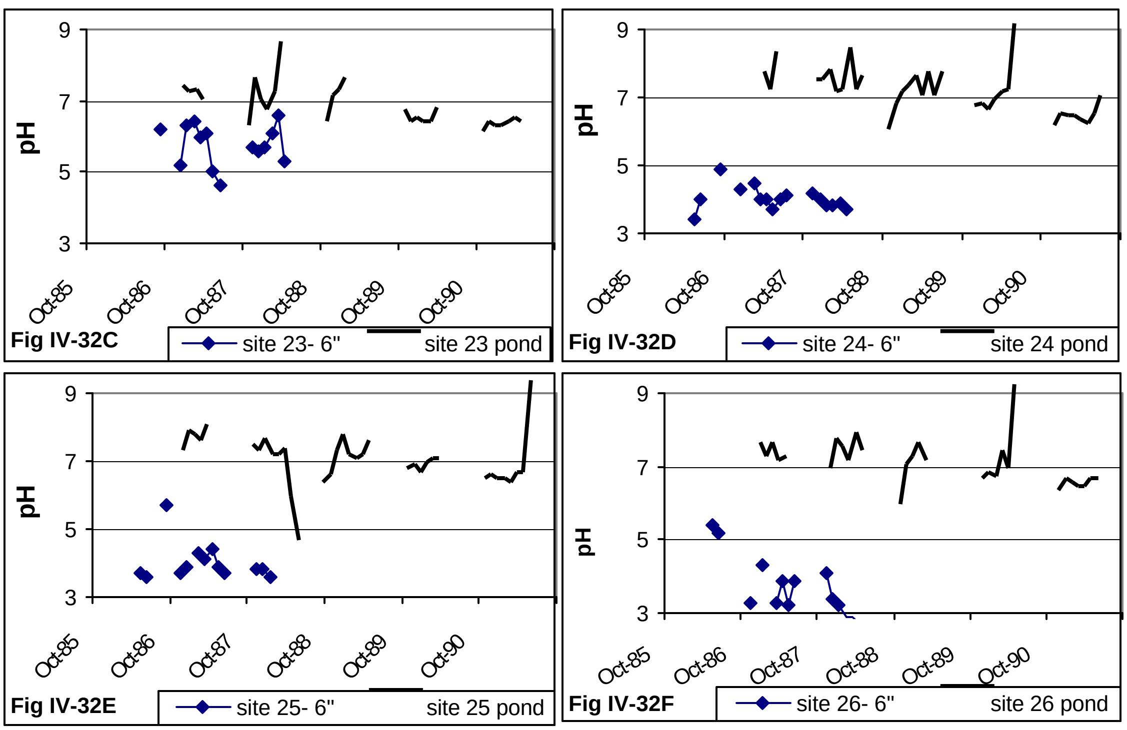


Figure IV-32C-F. Pond water and soil water pH values from Gum Tree sites 23-26.

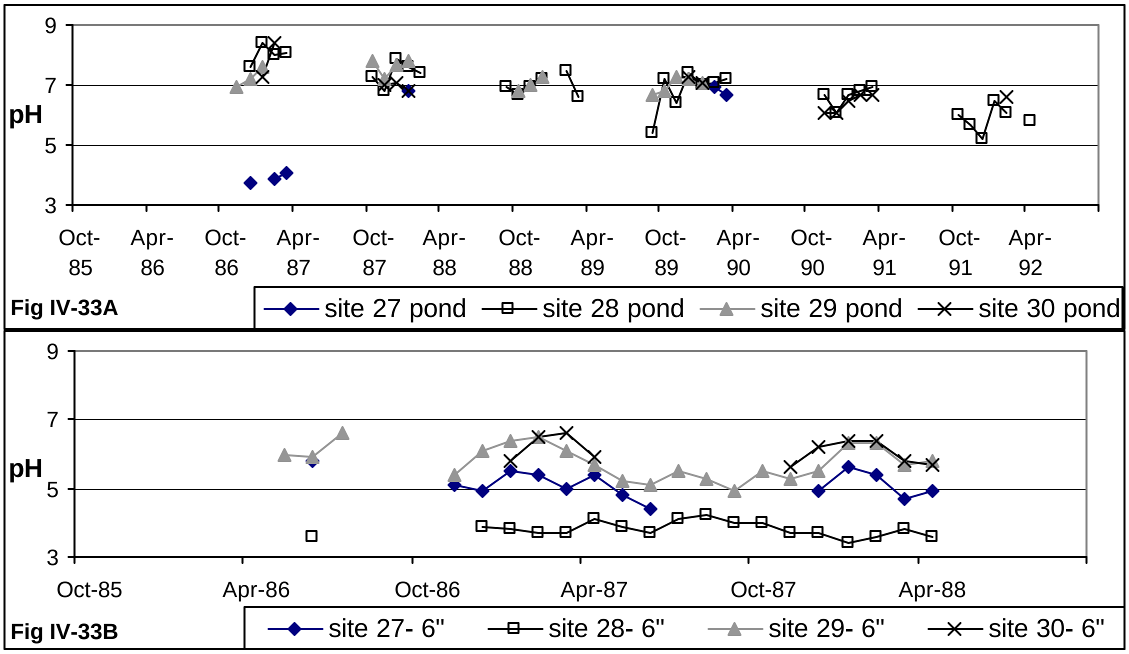


Figure IV-33A. Pond water pH values from sites 27-30 on Grizzly King.
Figure IV-33B. Soil water pH values from sites 27-30 on Grizzly King.

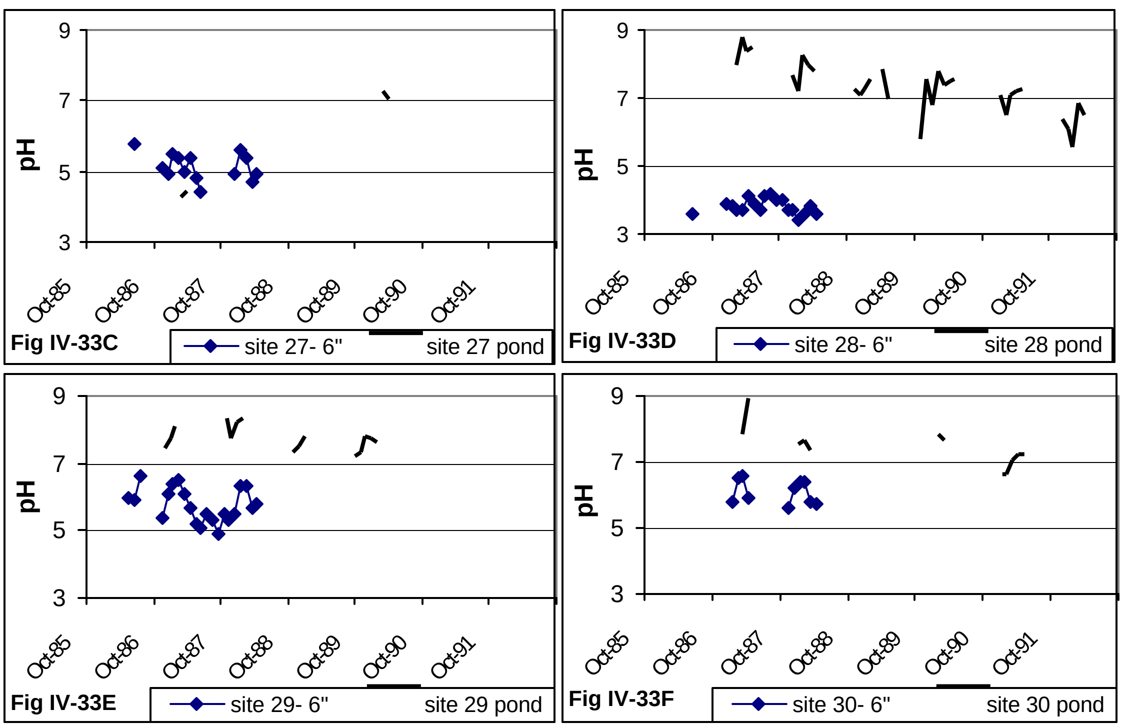
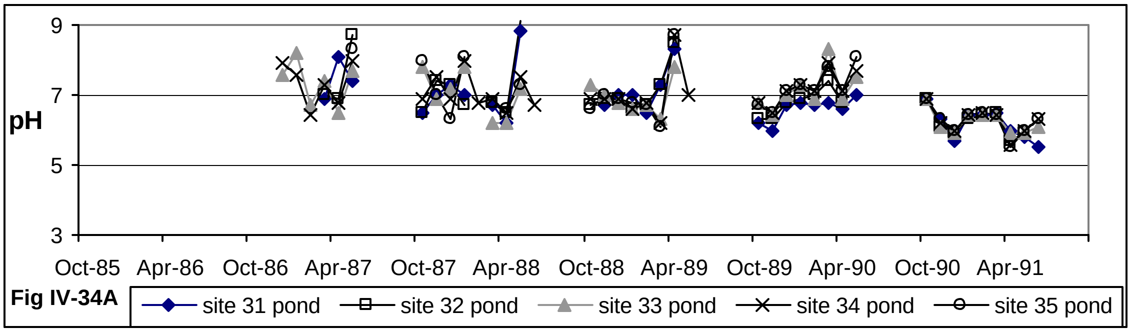


Figure IV-33C-F. Pond water and soil water pH values from Grizzly King sites 27-30.



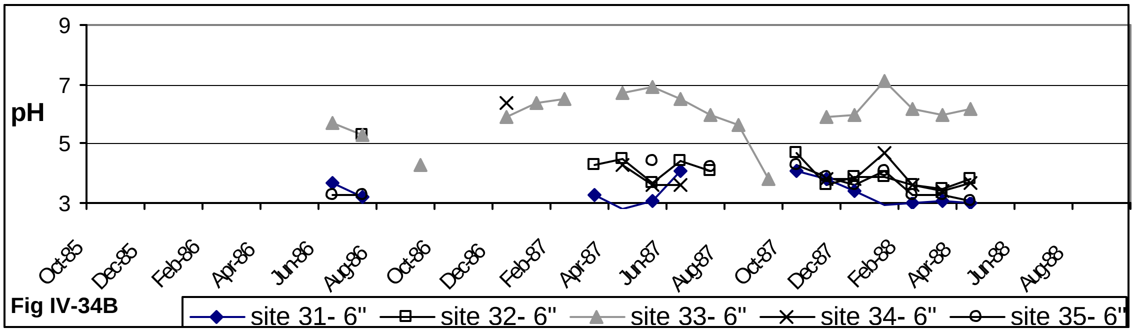


Figure IV-34A. Pond water pH values from sites 31-35 on Sprig Club.
Figure IV-34B. Soil water pH values from sites 31-35 on Sprig Club.

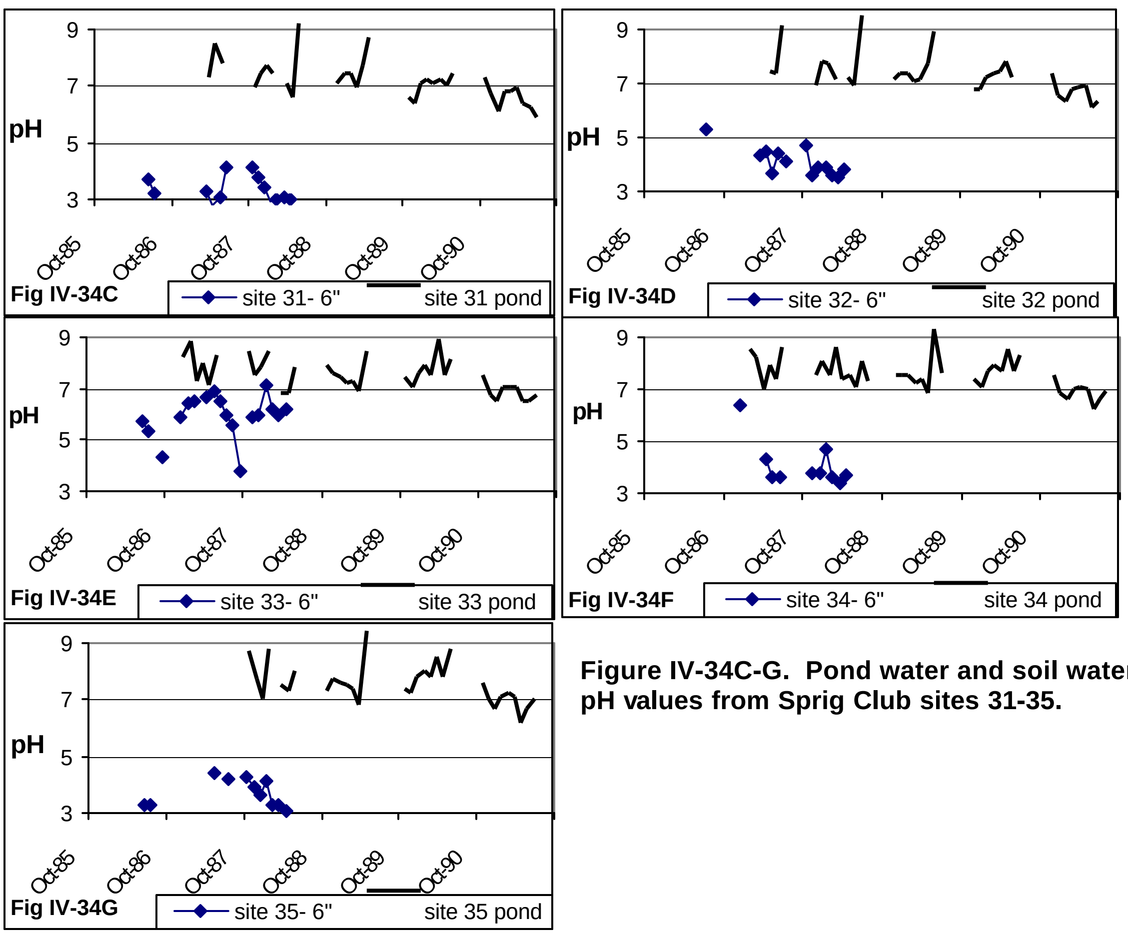
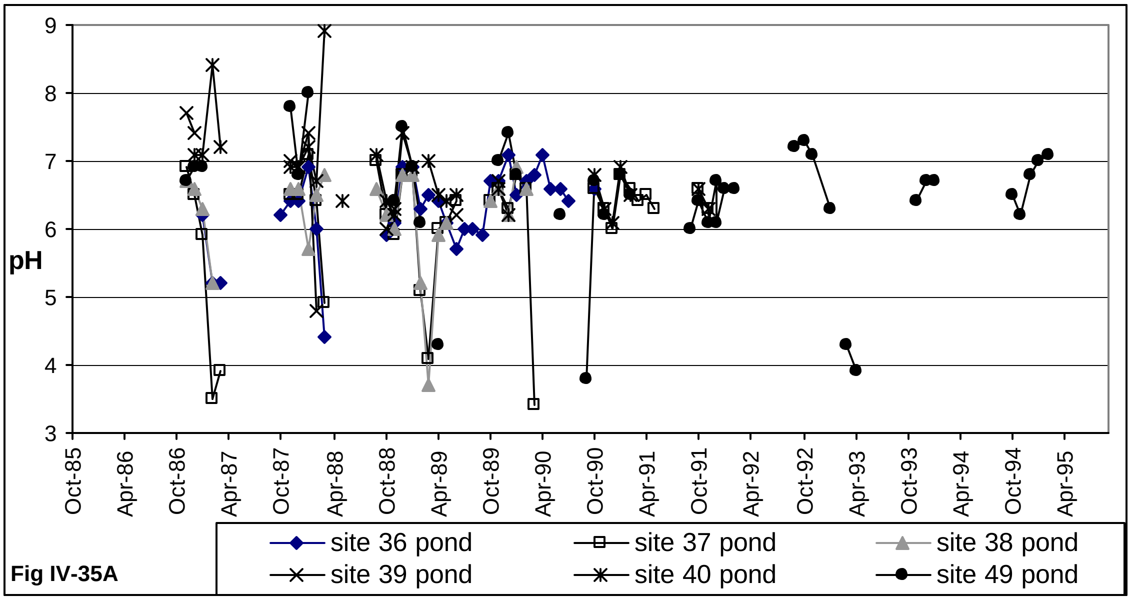


Figure IV-34C-G. Pond water and soil water pH values from Sprig Club sites 31-35.



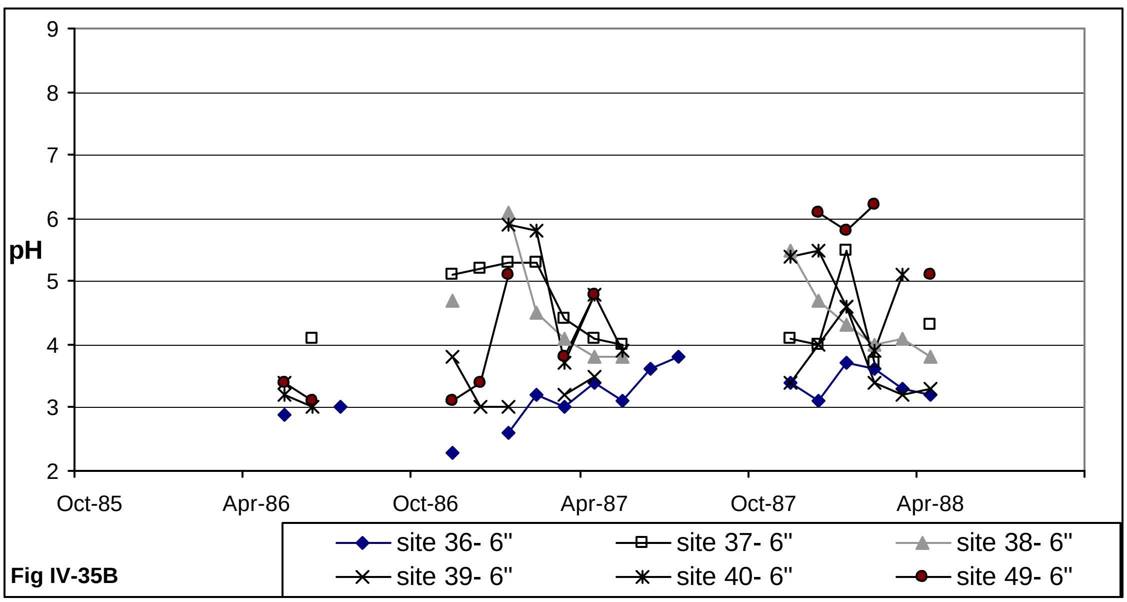


Figure IV-35A. Pond water pH values from sites 36-40 and 49 on Grizzly Island.
Figure IV-35B. Soil water pH values from sites 36-40 and 49 on Grizzly Island.

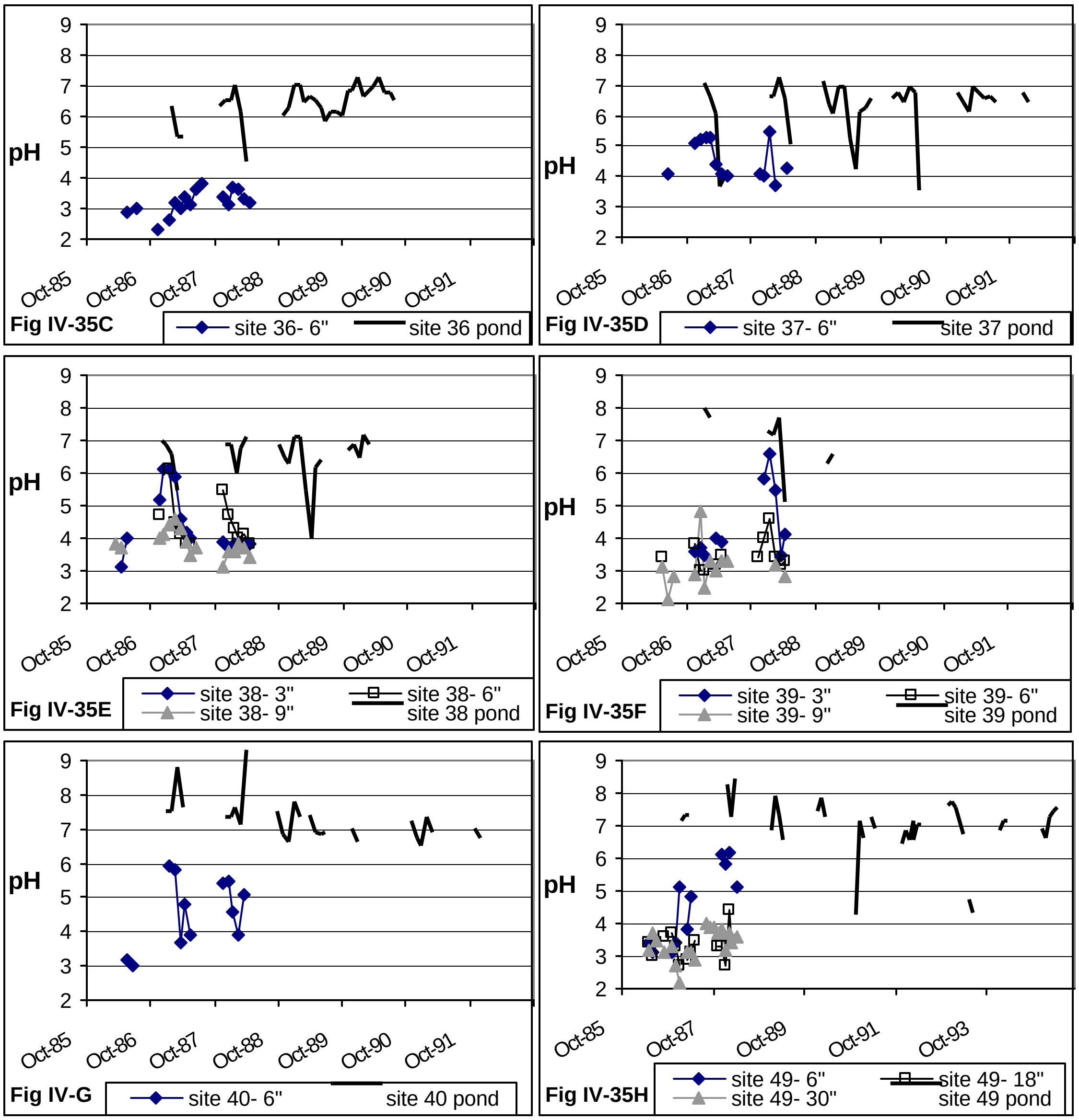


Figure IV-35C-H. Pond water and soil water pH values from Grizzly Island sites 36-40 and 49.

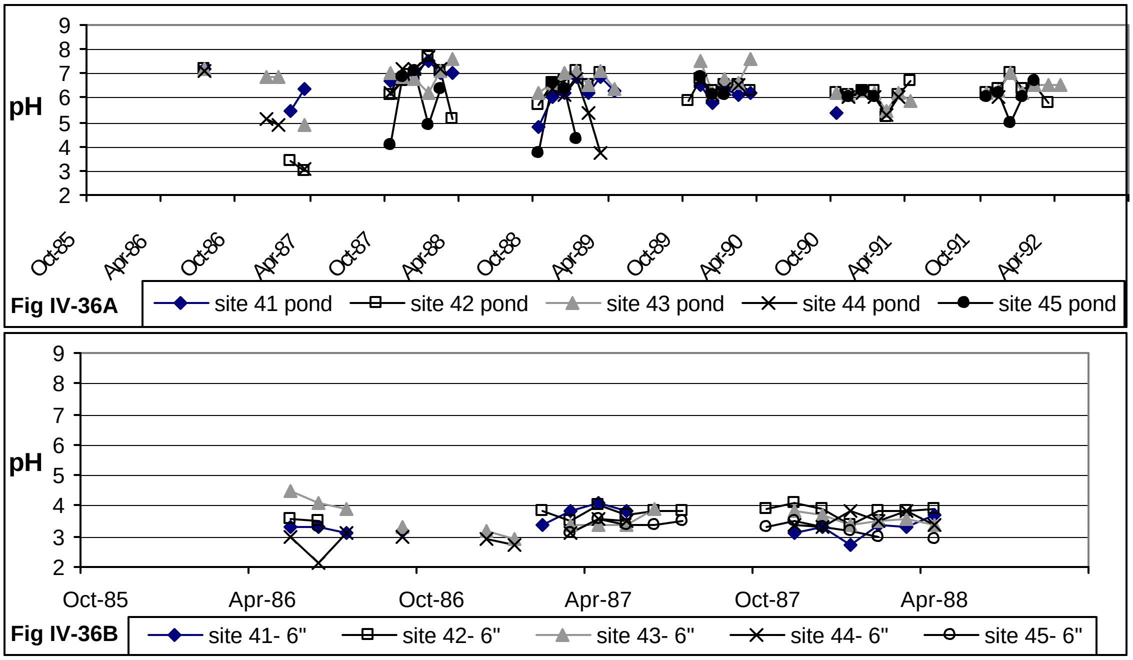


Figure IV-36A. Pond water pH values from sites 41-45 on Mallard Club.
Figure IV-36A. Soil water pH values from sites 41-45 on Mallard Club.

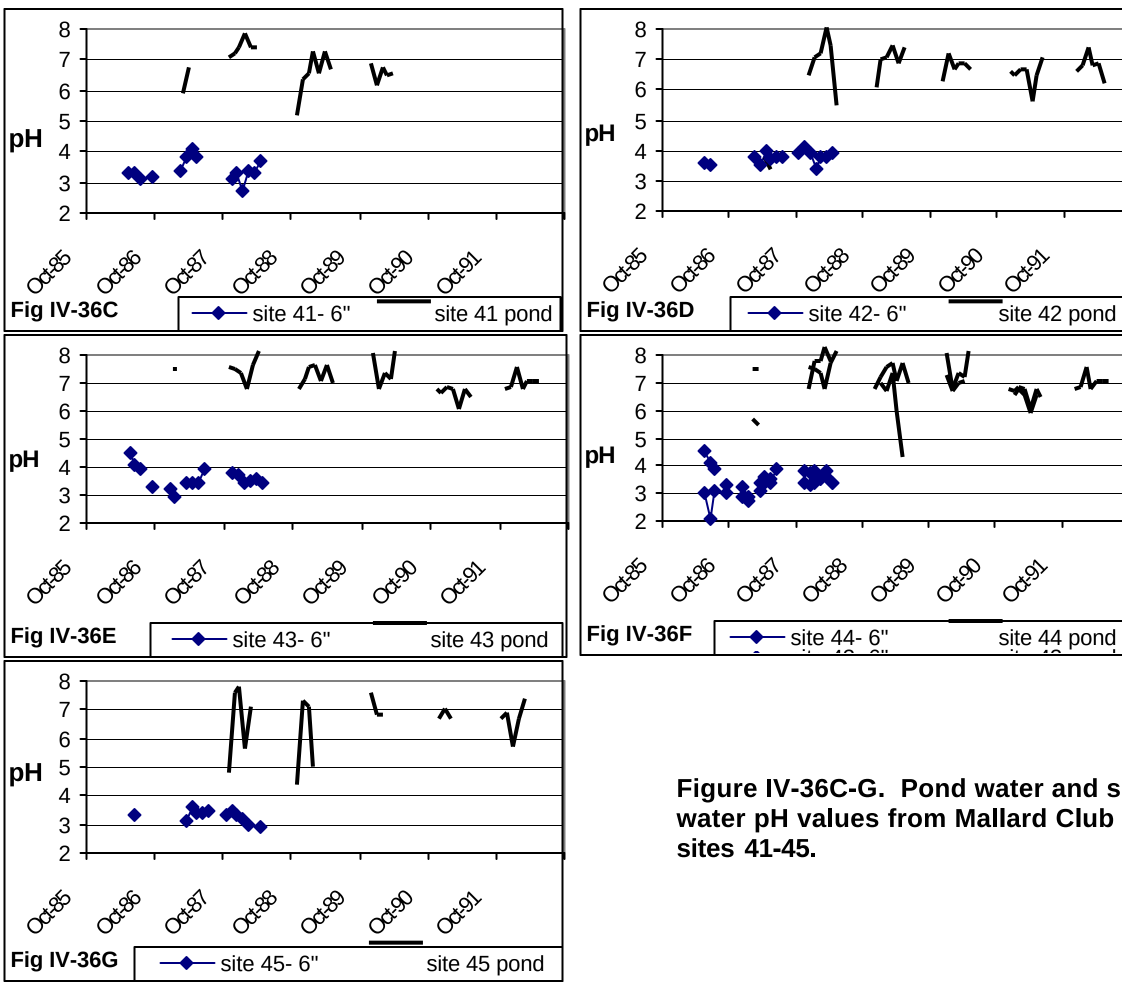
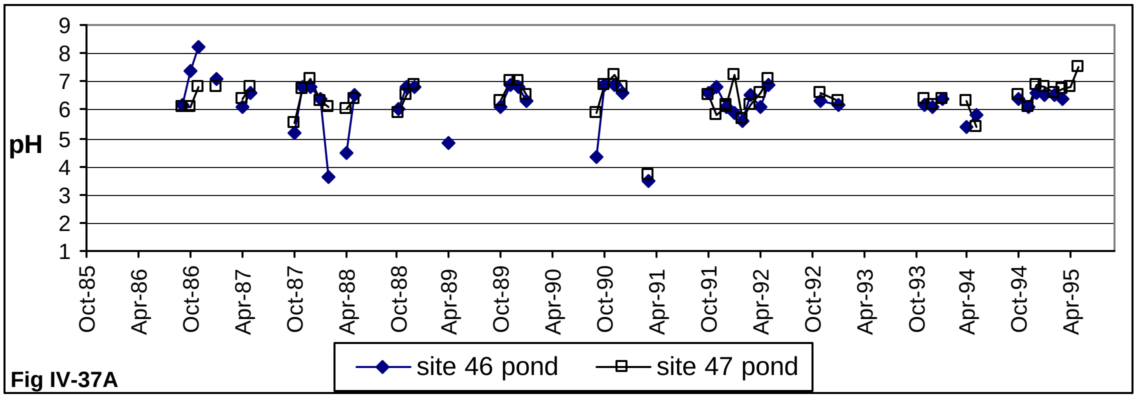
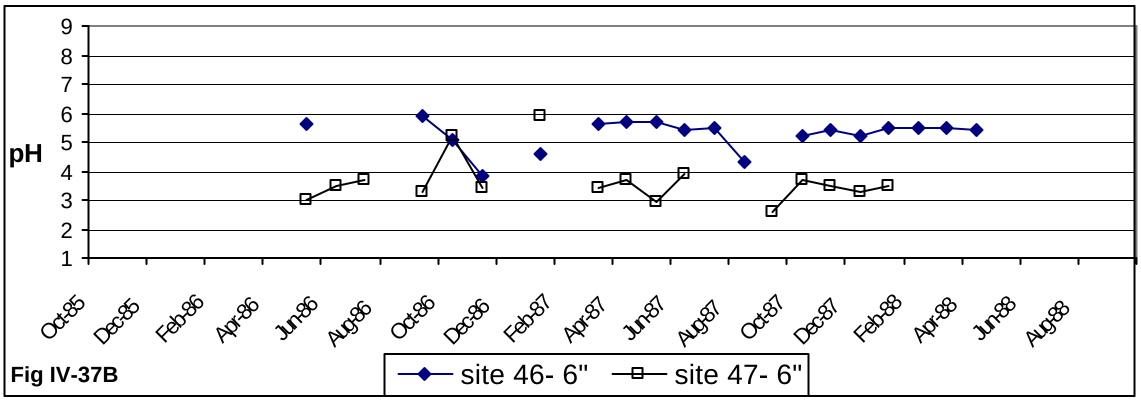
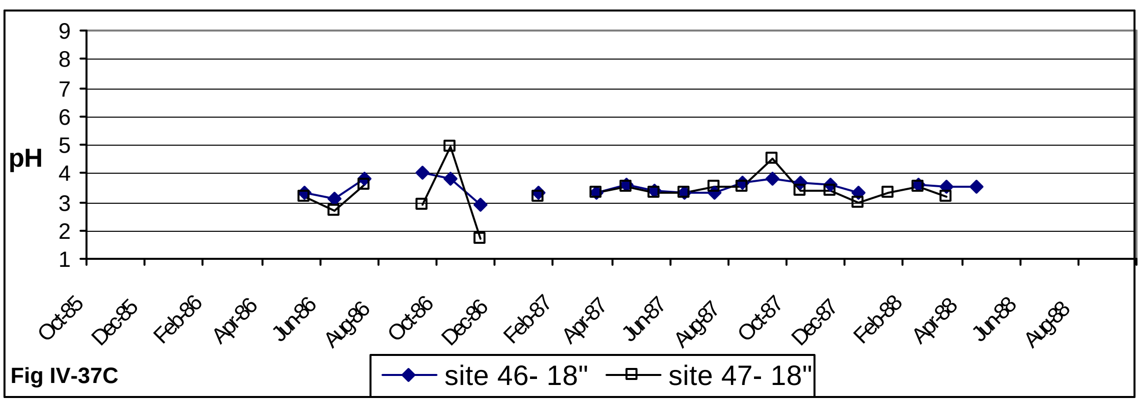


Figure IV-36C-G. Pond water and soil water pH values from Mallard Club sites 41-45.







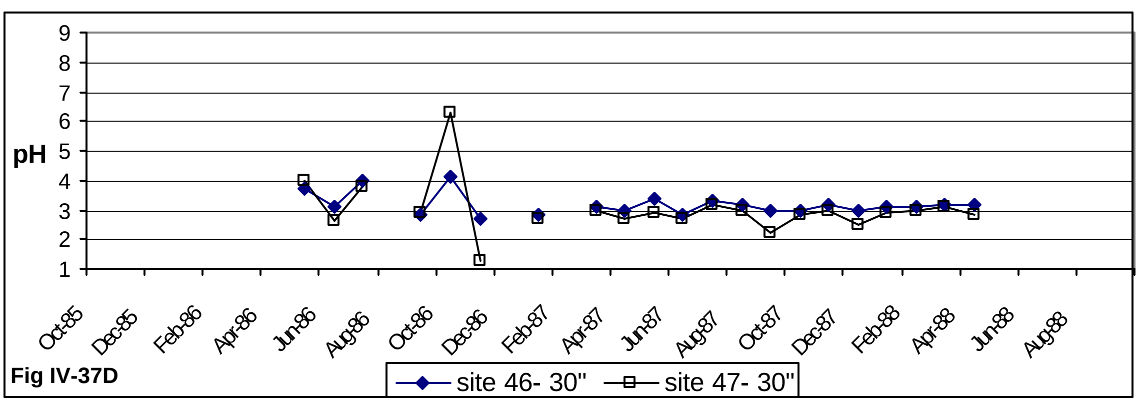
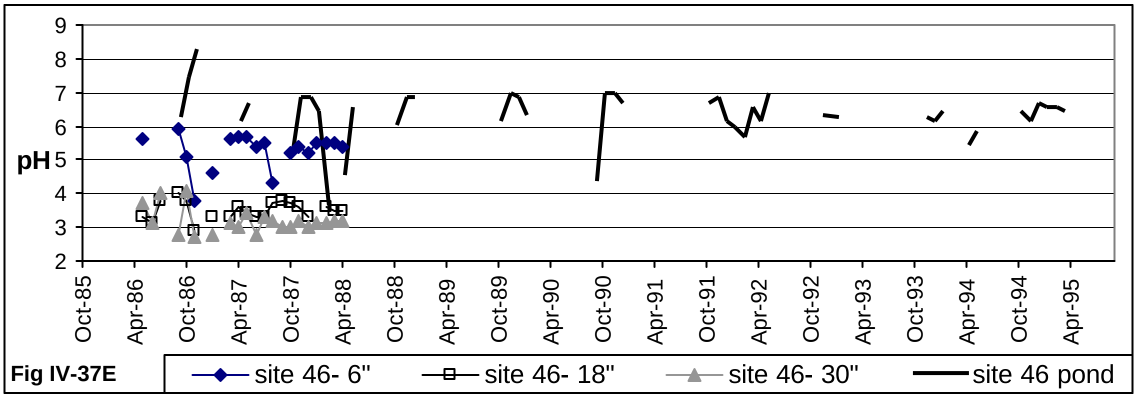


Figure IV-37A. Pond water pH values from sites 46 and 47 on West Family Club.
Figure IV-37B-D. Soil water pH values (at 6", 18", and 30" depths, respectively) from sites 46 and 47 on West Family Club.



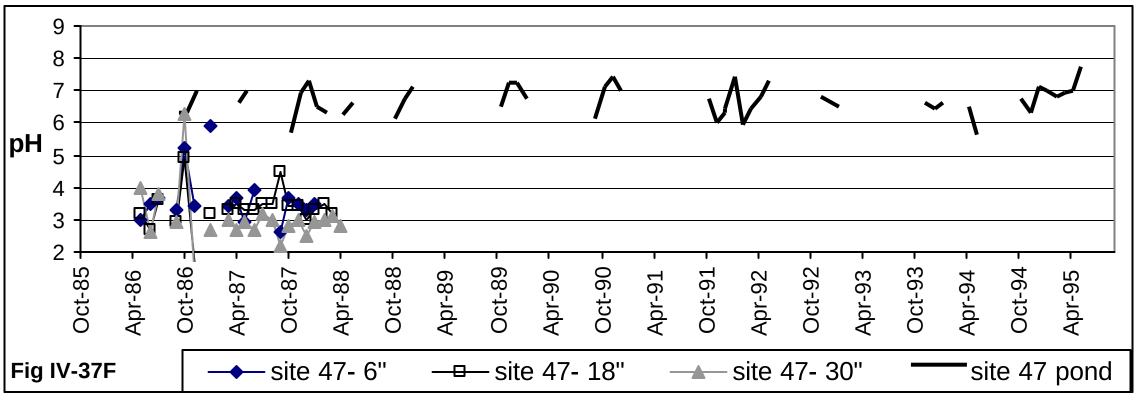


Figure IV-37E. Pond water and soil water pH values from Site 46, West Family Club.
Figure IV-37F. Pond water and soil water pH values from Site 47, West Family Club.

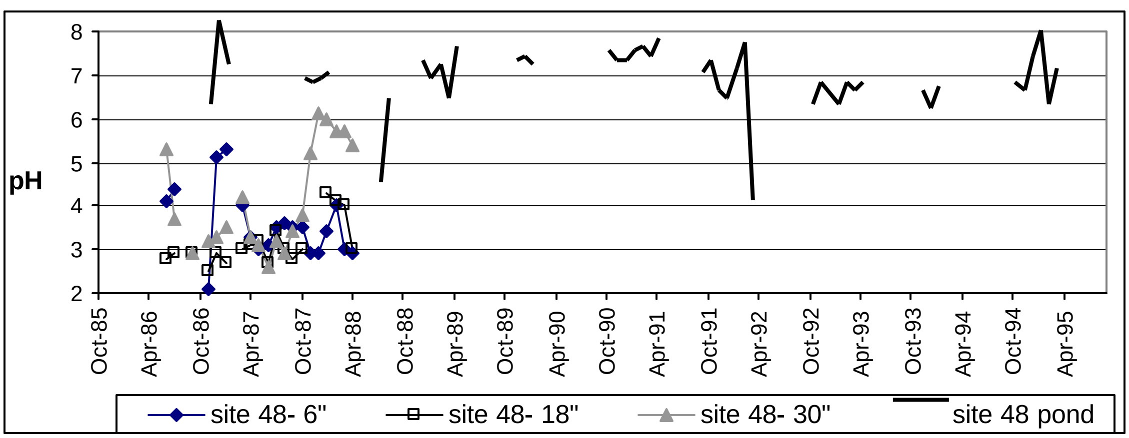


Figure IV-38. Pond and soil water pH values from site 48, Goodyear Slough Unit.

C. Conclusion

Pond water SC was usually closely related to the SC of the water that was used to flood the ponds. This relationship was strengthened by management practices that facilitated effective circulation, such as primary and secondary ditches and adequate intakes and drains. The pond water SC usually exceeded that of applied water by more than 5 mS/cm during flood-up. It is hypothesized that this increase in pond water SC was due to salts that accumulated near the soil surface during summer evaporation and then dissolved into the pond water and increased the concentration of solutes. The pond water SC also exceeded the applied water SC when the ponds drained in the spring, possibly because the water picked up salts as it drained, and evaporation may have caused the concentration of salts to increase. Pond water SC tended to be higher in the western marsh, where applied water SC was higher, but this was not a consistent trend.

D. Recommendations

Future monitoring protocols would be dependent upon the goal of the monitoring. However, the on-site monitoring results have shown that the following changes would provide more useful data:

- Collect pond water samples from multiple sites in the pond to more accurately assess pond water SC and to minimize microsite effects on data analysis results
- Collect samples from intakes, drains, and ditches to determine management effects
- Collect data more often than monthly to assess effects of water management actions, precipitation, and applied water SC

- Incorporate more thorough QA/QC procedures, including field QC.

Chapter V
Drain Water Specific Conductance

Drain water salinity data were measured for a limited period, with length of monitoring varying depending on the site (Table I-6). All monitoring occurred within the period of October 1981 through June 1994.

A. Drain Water Specific Conductance Data Evaluation

1. Method Evaluation
Specific conductance data were continuously monitored at 15-minute intervals. Data were recorded at selected sites by Enviro Lab DL-150 or DL-800 data loggers modified to accommodate a salinity sensor.

2. Quality Assurance/Quality Control
Channel and drain water were continuously monitored at 15-minute intervals. Instruments were checked weekly for accuracy against reference solutions prepared by DWR's Bryte Chemical Laboratory, and calibrated when necessary.

3. Sample Representativeness
Drain water SC was measured at the following seven monitored ownerships: Morrow Island, Tule Belle, Gum Tree, Joice Island, Mallard, Grizzly King, and Grizzly Island. Drain water SC for was determined by placing an SC probe in one drainage ditch at each monitored ownership, just inside of the drainage gate. This method may not have provided representative samples due to the existence of multiple drains at each monitored ownership. All of the monitored ownerships have at least three drains (most have more) at various locations along the monitored ownership boundaries. The SC of the drain water at one drain may not be the same as the drain water SC at the other drains. Clubs such as Tule Belle, Mallard, Grizzly King and Grizzly Island all had significantly variable pond water SC values within each monitored ownership. This would suggest that the water in various drains within each monitored ownership would also be different.

Other factors influencing the representativeness of the drain water SC samples include evaporation and precipitation. Since the drain water SC was continually monitored in the drainage ditch, significant precipitation could fill the ditch and result in a non-representative SC value. Conversely, evaporation of standing water in the drainage ditch could result in drainage water SC values that are biased high.

4. Data Limitations
No data quality limitations were found. However, due to limits on sample representativeness, drain water SC values were only used as indications of general trends of drain water salinity. Changes in drain water SC during precipitation events were considered to be due to dilution of water within the drainage ditch. Drain water SC

values measured after final pond drawdown were dismissed from evaluation since they likely represent the SC of stagnant water remaining in the drainage ditch.

B. Data Results

Drain water SC was collected continuously in 15-minute intervals at seven monitored ownerships in the marsh during the study period (Table I-6). Minimum, maximum and average daily SC values were determined for each 24-hour period. Monthly maximum, minimum, and average SC values were calculated using the daily maximum, minimum, and average SC values (Figures V-1 through V-7).

In some cases, data were not available for one or more days because a monitored ownership was not draining, or because of equipment failure. If data were not available for ten or more days for any given month, the average SC value was compared with the SC for the preceding and following month, and management events were reviewed, to see if the SC value appeared to be biased. This evaluation revealed three data points that appeared to be significantly different from the data for either the preceding or following month. Two of the data points were at site A-60 for the months of May 1988 and October 1989. Review of the PSR and management data for both months indicates that the values can be explained by water management events. The third data point was at site A-53 for the month of December 1990. Similar to the other two points, this point can also be explained by water management events.

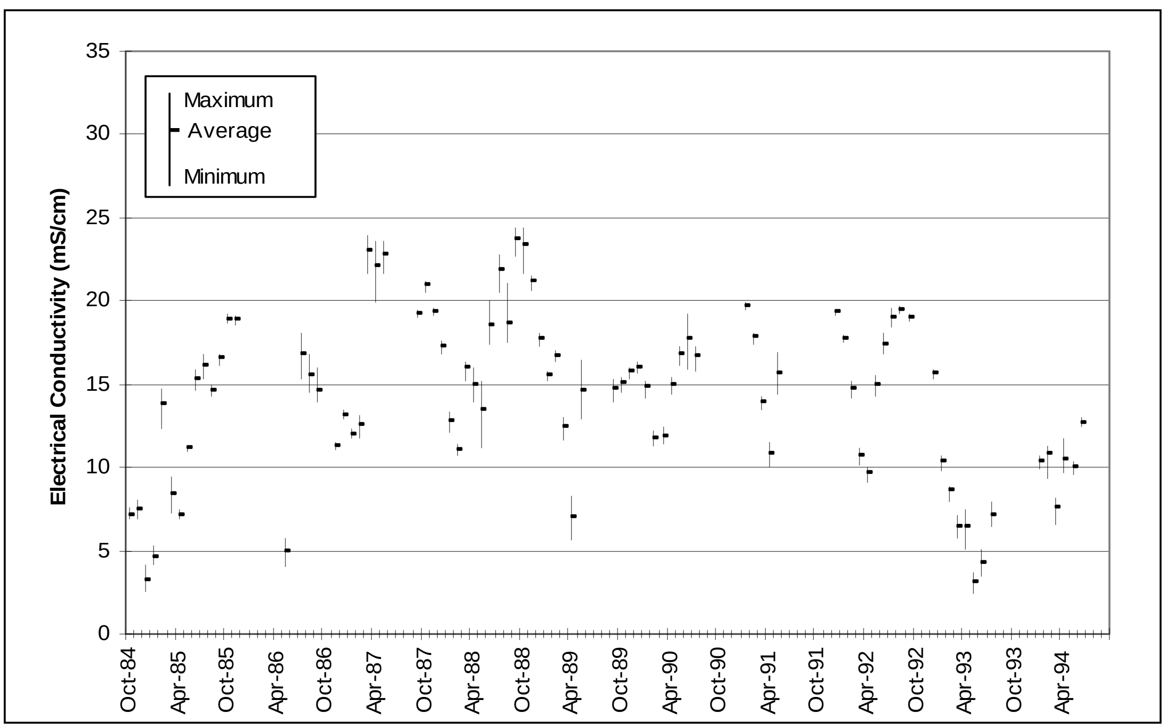


Figure V-1. Range of monthly EC drain water values at Morrow Island (A52).

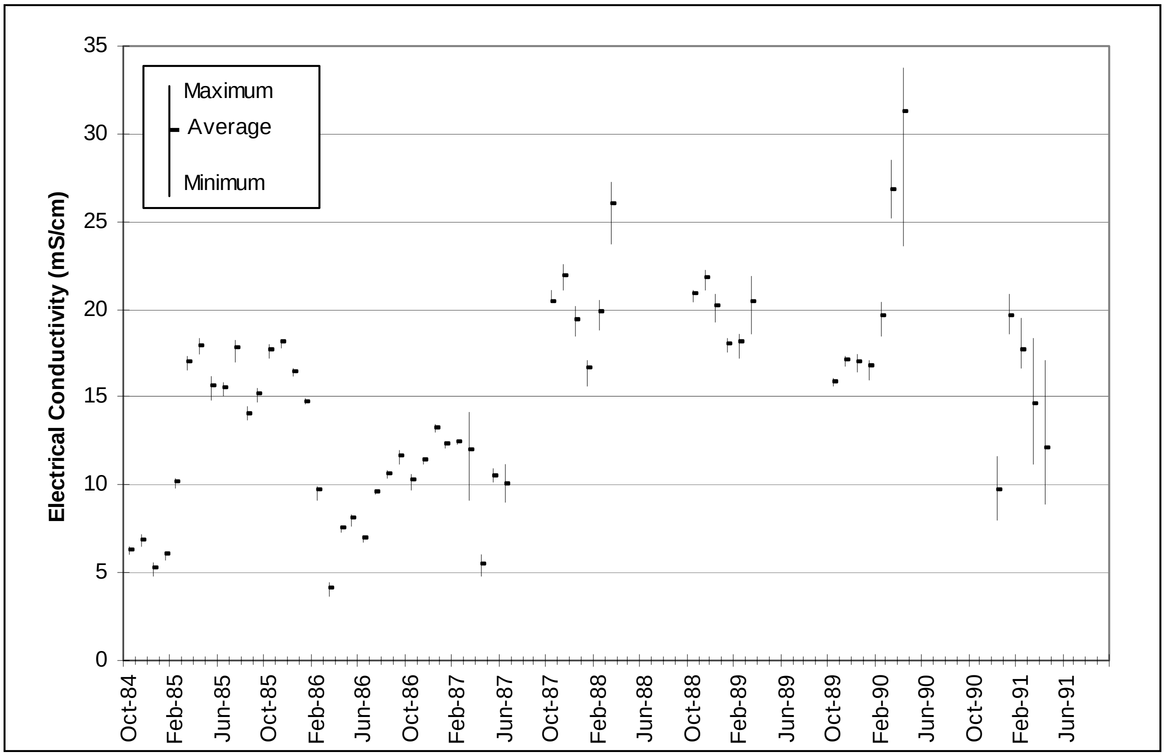


Figure V-2. Range of monthly EC drain water values at Tule Belle (A53).

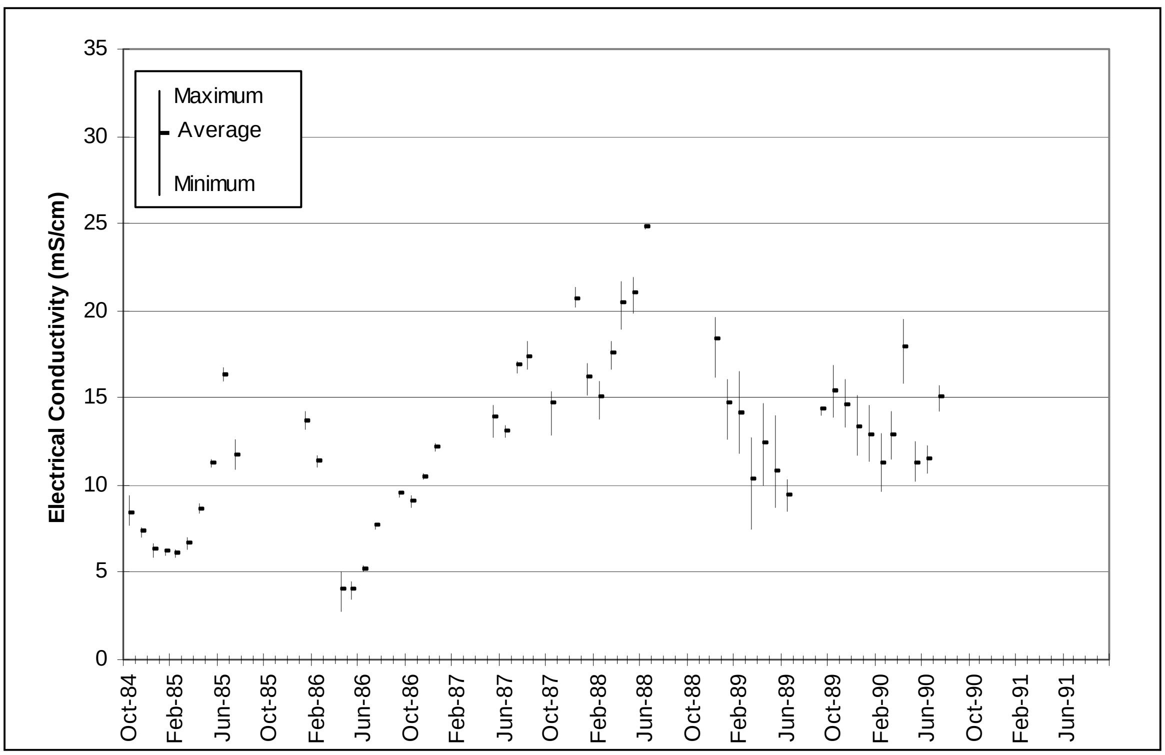


Figure V-3. Range of monthly EC drain water values at Gum Tree (A58).

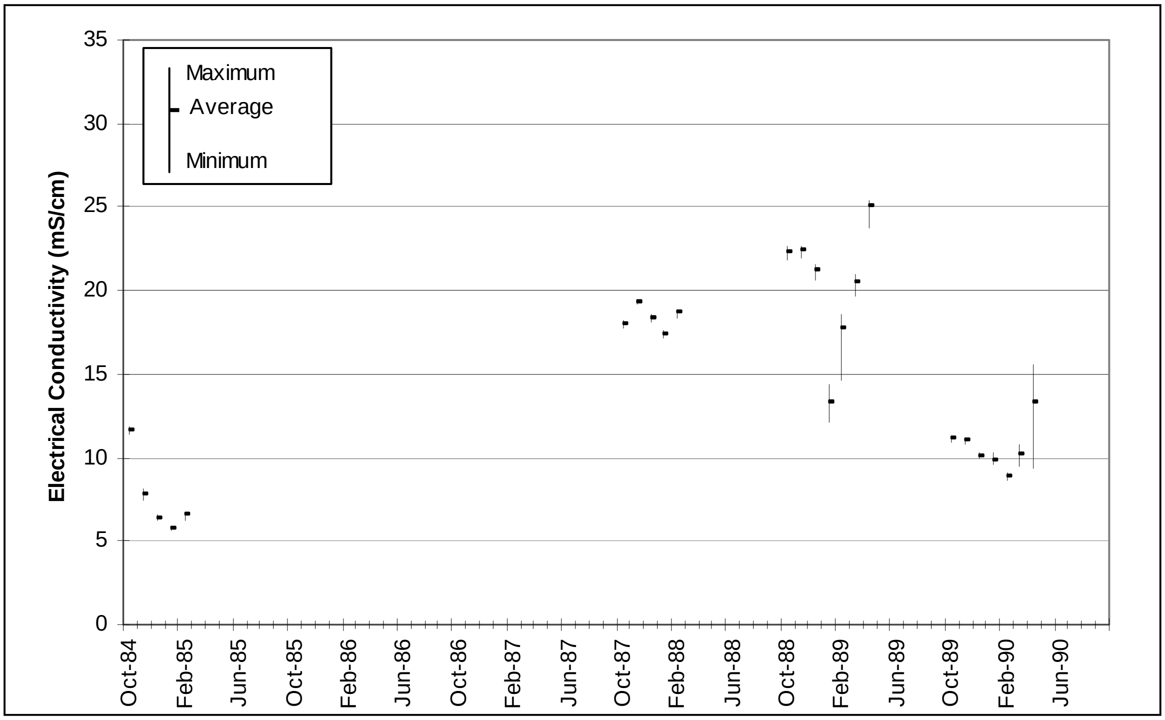


Figure V-4. Range of monthly EC drain water values at Joice Island (A59).

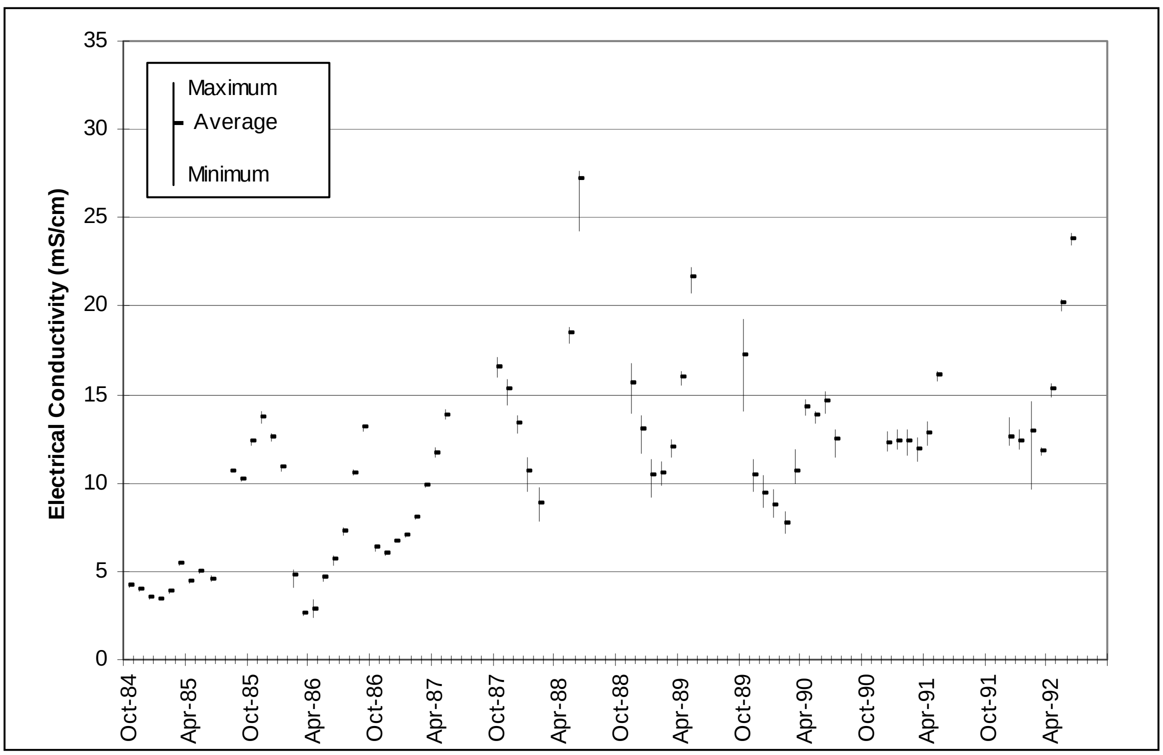


Figure V-5. Range of Monthly EC Drain Water Values at Mallard Farms (A60).

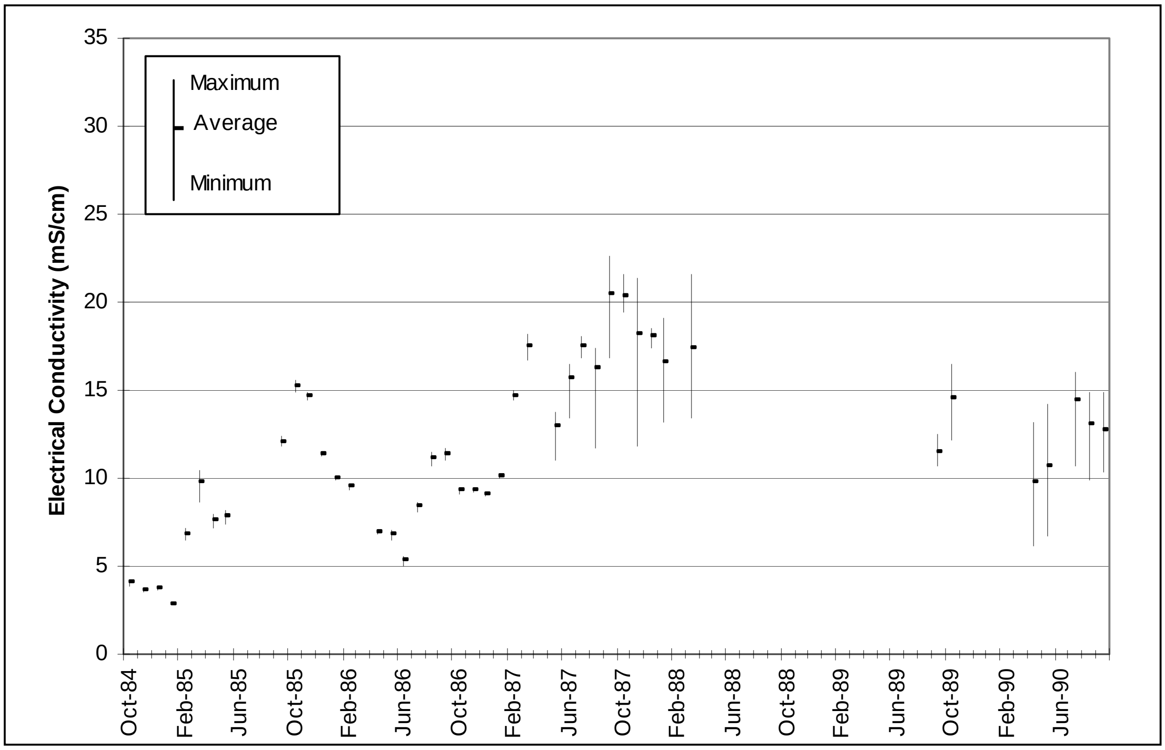


Figure V-6. Range of monthly EC drain water values at Grizzly King drain (A61).

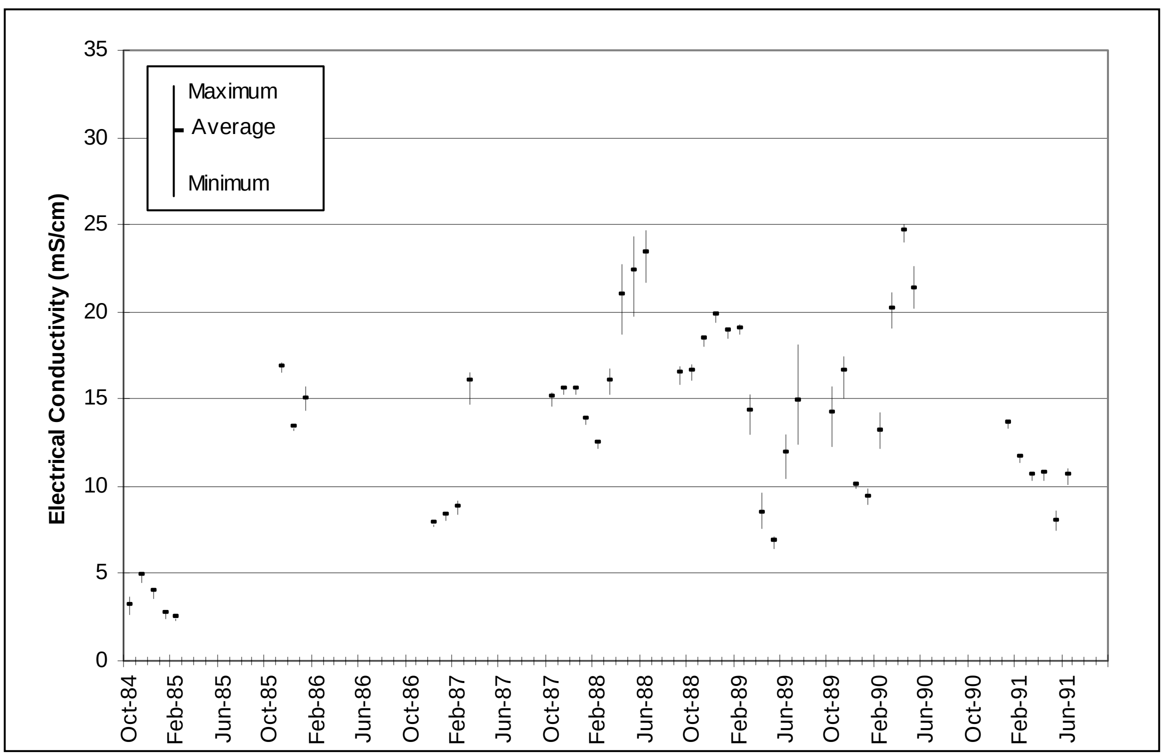


Figure V-7. Range of Monthly EC Drain Water Values at Grizzly Island Drain (A63).

1. Comparison of Drain Water SC with Pond Stage

Data were analyzed to determine if changes in pond depth, such as leach cycles, coincided with apparent changes in drain water EC. Graphs were made comparing the drain water EC, pond depth, and precipitation for three monitored ownerships: Morrow Island, Tule Belle, and Mallard. The graphs (Figures V-8 through V-14) did not reveal any strong relationships between pond depth and drain water salinity. Unfortunately, information is not available for drain water volume or for daily soil water EC, making it difficult to determine if SC in drain water is increasing because salts from the soil are leaching or because of evaporation in the drain. It does generally appear that clubs practicing some form of leaching have more variable drain water SC values than clubs that just flood and drain.

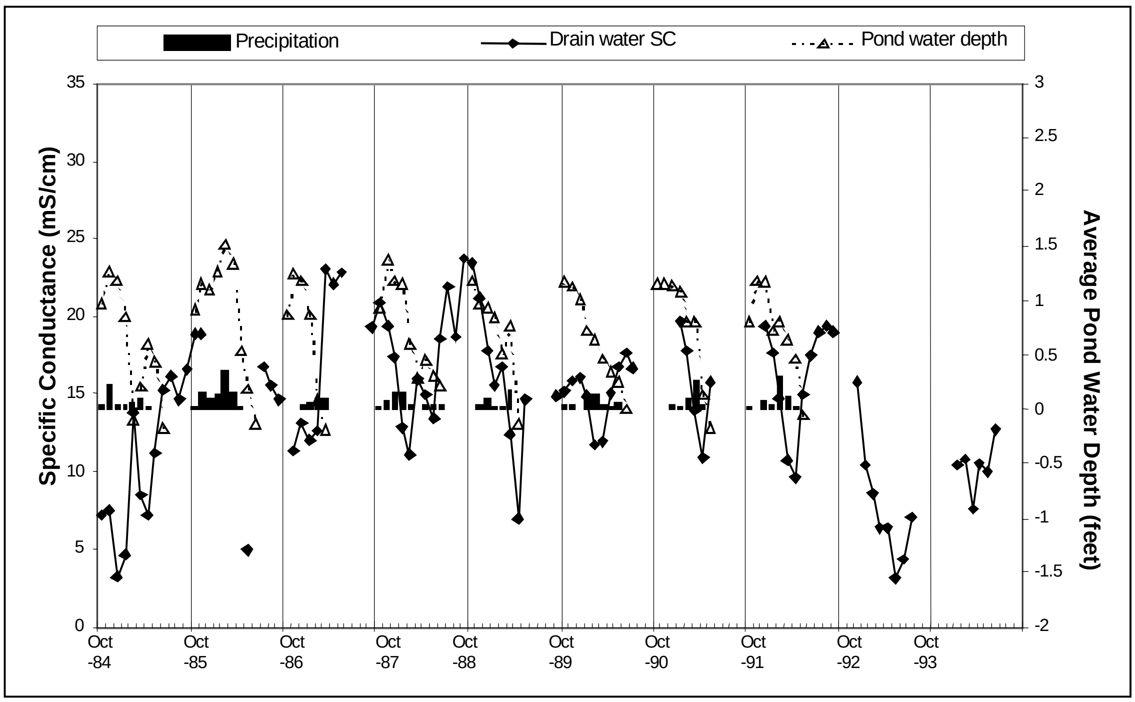


Figure V-8. Average monthly pond water level and drain water SC at Morrow Island (A52).

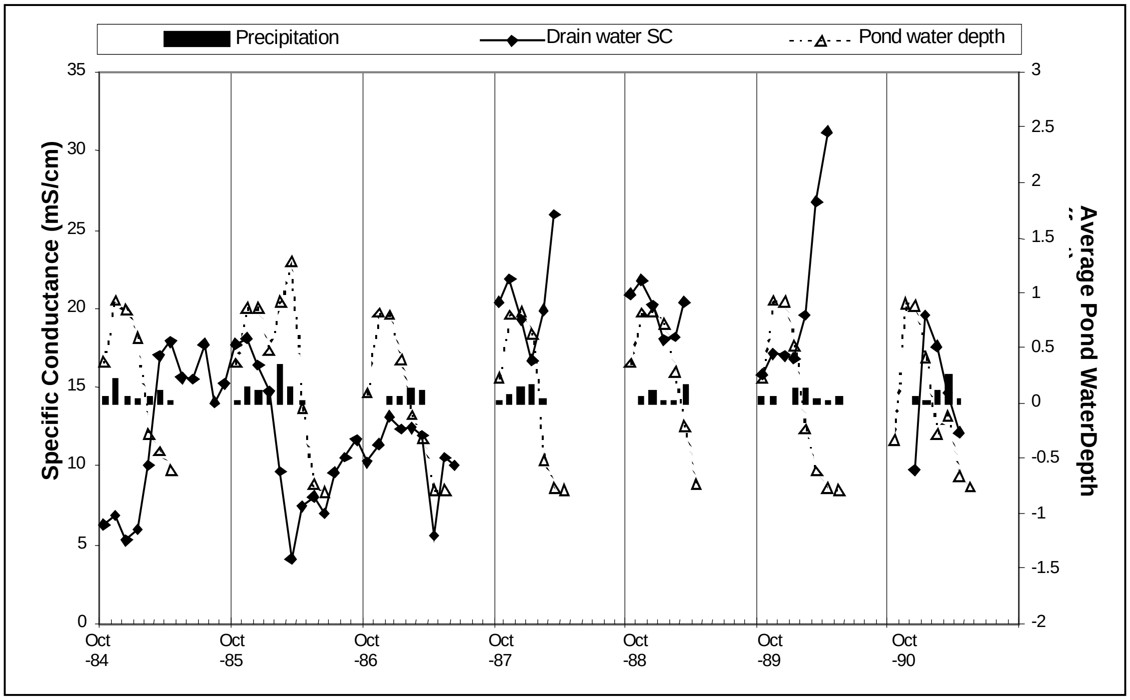


Figure V-9. Average monthly pond water level and drain water SC at Tule Belle (A53).

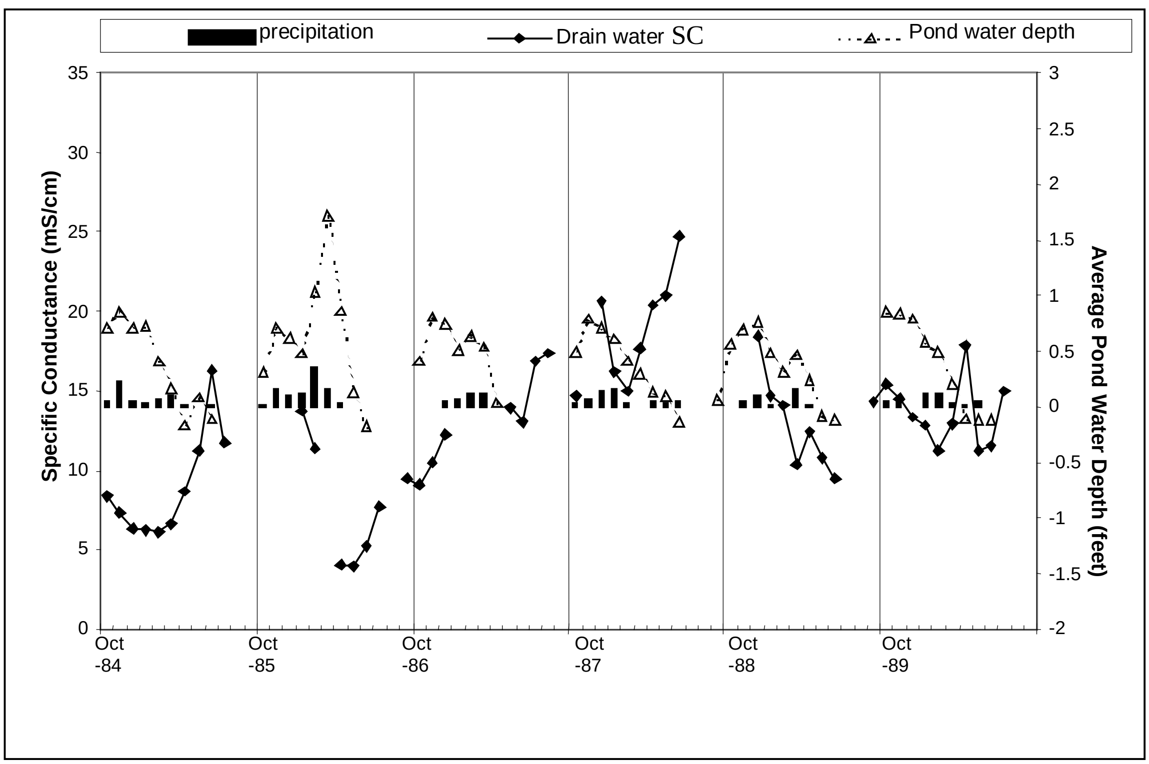


Figure V-10. Average Monthly Applied Water and Drain Water EC at Gum Tree (A58).

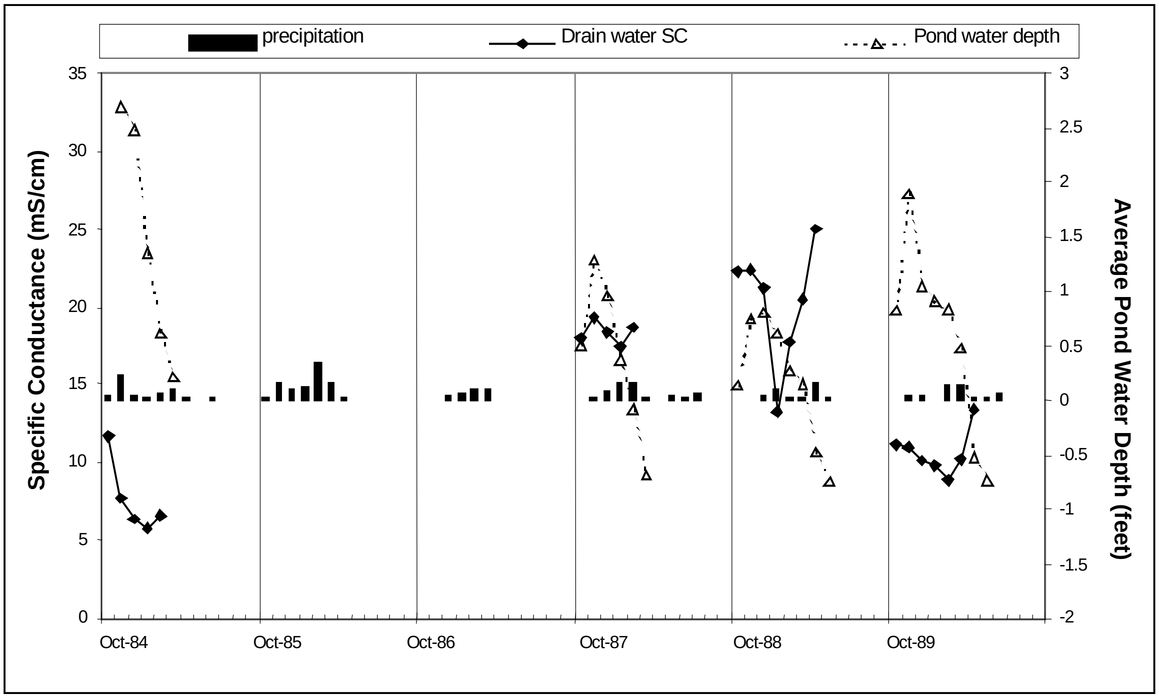


Figure V-11. Average Monthly PSR Level and Drain Water EC at Joice Island (A59).

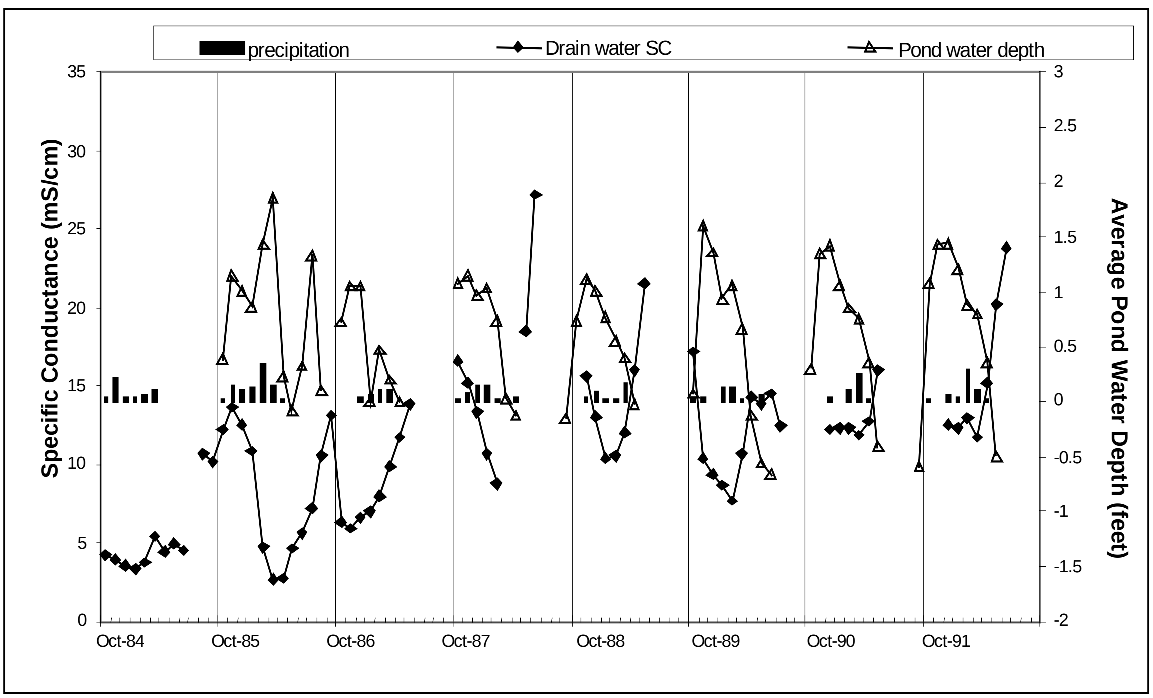


Figure V-12. Average Monthly PSR Level and Drain Water EC at Mallard Farms (A60).

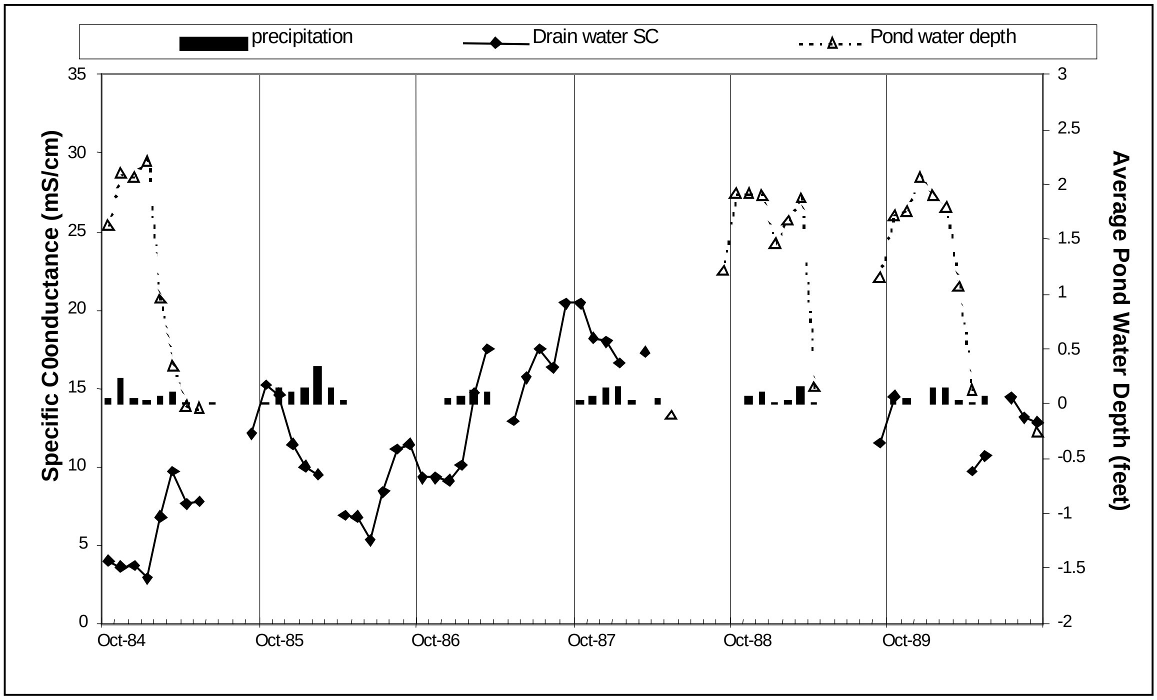


Figure V-13. Average Monthly PSR Level and Drain Water EC at Grizzly King (A61).

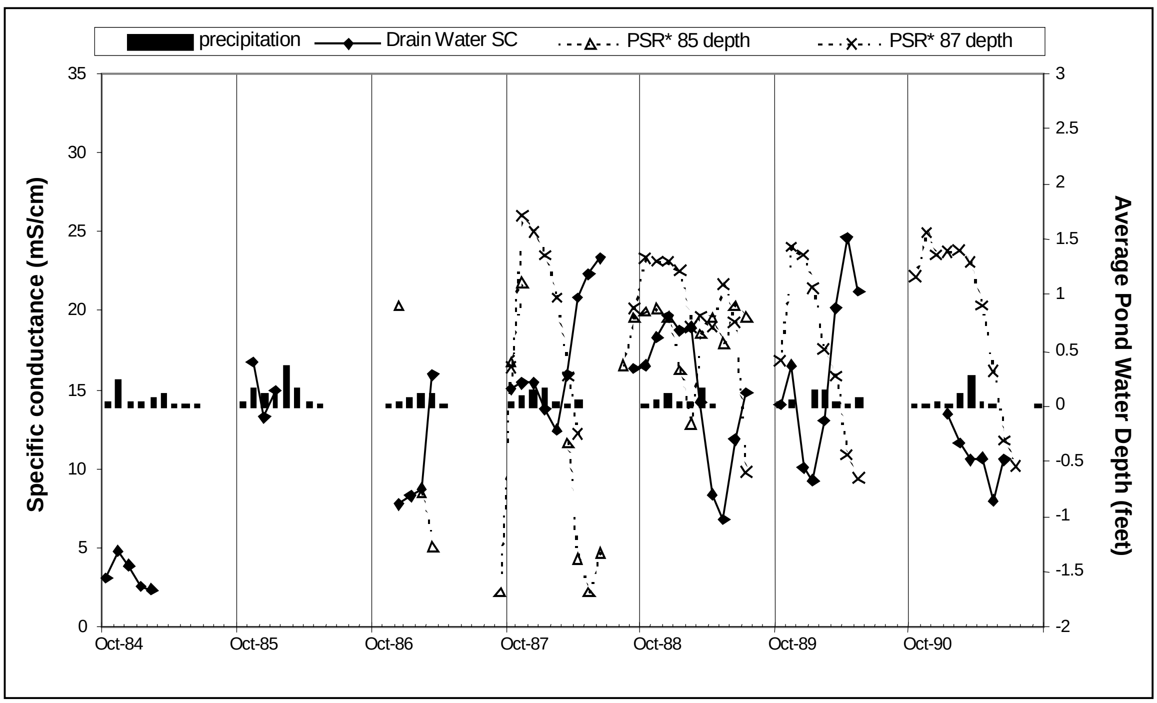


Figure V-14. Average Monthly PSR Level and Drain Water EC at DFG Grizzly Island (A63).

2. Drain Water Variability within Water Years

The variability of monthly drain water SC values was evaluated for individual years to determine if any patterns were apparent. It was found that drain water SC values were generally constant from October through December, after pond flood up and during hunting season when ponds have reached shooting level (Figures V1-V7). Clubs leave the intake and drain gates partially open during this period so water is constantly circulating through the ponds. Therefore, it is not expected that drain water SC would vary significantly during this period.

The variability in drain water SC increased during leaching events, which usually occur during January and February. Variability also increased after final pond drawdown, which usually occurs between March and May. Increased variability in SC during the leaching periods is likely due to flushing of salts from the soil. As salts are flushed out, the maximum drain water SC increases. Increases in drain water SC after final pond drawdown were likely the result of evaporation of drainage water remaining in drainage ditches.

3. Drain Water Variability between Water Years

Drain water SC variability between water years was evaluated for any apparent patterns. Generally, drain water SC variability was fairly small during water years 1985 and 1986 (range of 2 mS/cm). Variability increased in water years 1987 through the end of the study period, up to a range of 10 mS/cm. Average drain water SC generally followed the same trend as did variability in EC. Average SC levels increase during the period from 1987 through the end of the study, corresponding with six consecutive dry and critical water years. During this timeperiod, soil water and pond water salinity also generally increased (see chapters 4 and 6). It is reasonable to expect that greater soil water salinity would result in greater average drain water salinity as well as greater variability in drain water salinity.

C. Conclusions

The Suisun Marsh Monitoring Agreement states that “A point on each Monitored Ownership shall be monitored continuously for [drain water] SC by DWR”. The Monitoring Agreement also states “It is the intent of the parties to reduce the scope of the monitoring program, particularly monitoring on Individual Ownerships, as soon as sufficient information is available…”. Based on these statements, the requirements of the Monitoring Agreement were met by the monitoring program. Although the intent of the required drain water monitoring was not stated specifically, it can be assumed it was to help determine the efficacy of management practices in removing salts from the soil. In this respect, the drain water monitoring effort did not fulfill the intended purpose of the monitoring program. Given the limitations of the data, it is not possible to determine if any correlation between management practices, soil water salinity and drain water SC exists.

D. Recommendations

The method used to collect drain water SC provided acceptable data. However, the scope of the monitoring activities was too limited to provide enough information for a proper evaluation of the effects of pond management activities on drain water EC. Recommendations for future data collection include:

- Increasing the number of monitoring sites on each monitored ownership to determine variability within each pond
- Measurement of drainage flow/volume
- More frequent monitoring of pond/soil water SC levels

Chapter VI
Soil Water Specific Conductance

Soil water monitoring sites were located in ponds managed for waterfowl hunting throughout the Suisun Marsh. These sites were usually inundated for several months of the year. Soil water SC was measured monthly at sites on the monitored ownerships during the period August 1984 to September 1995 (Table I-6). During this time, the number and location of monitored sites varied based on site access and/or management practices.

A. Soil Water Specific Conductance Data Evaluation

1. Method Description

The Monitoring Agreement required that "soil water SC will be monitored by DWR …"

Soil water was collected in soil water extraction tubes constructed from PVC pipe with a porous ceramic cup at the bottom. A vinyl tube extended from the bottom of the ceramic cup up through a rubber stopper inserted in the top of the PVC pipe. Soil water was extracted through the vinyl tube with a hand pump. After the water sample was collected, air was removed from the PVC pipe to create a vacuum and allow water to seep back into the ceramic cup.

The on-site monitoring program focused on two water management practices, early drawdown and late drawdown (discussed in Chapter 1 and shown in Figure I-6). Target plant species grown under these two management regimes have different growth habits and SC tolerances, therefore data collected at each site were pertinent to the particular water management regime. At late drawdown sites, water was collected from three soil tubes at a depth of 6 inches, the appropriate depth for monitoring soil water SC in the root zone of the target plant, alkali bulrush. At early drawdown sites, water was collected from nine tubes, with three each at 6, 18 and 30 inches because the roots of the target species, fat hen, penetrate deeper into the soil.

Water from the soil water extraction tubes was collected once each month within three days of the 15th of the month. Specific conductance and pH data were collected in the field for each water sample. Soil water pH was measured with a Beckman pH 21 pH Meter. Soil water specific conductance was measured using a Beckman RC 20 Conductivity Meter. Portions of each of the three samples taken at each depth were then pooled and sent to DWR's Bryte Laboratory for further analysis of total dissolved solids, specific conductance, and chloride concentration.

With this method, proper tube installation is essential to avoid "glazing" of the soil adjacent to the tube, which could impair the entry of water into the soil tube. No studies were done to assess possible "clogging" of the pores in the ceramic cup, therefore it is not known if the effectiveness of the tubes diminished over time. The amount of water collected was sometimes substantially different for each of the three depth-specific tubes, but the specific conductance of the three samples rarely varied more than 2 mS/cm.

2. Quality Assurance/Quality Control

a. Field Quality Control

EPA methods for sample collection, preservation, and handling of water were followed (USEPA 1993).

b. Laboratory Quality Control

Laboratory quality control procedures listed in EPA methods (USEPA 1993) were followed. This included the analysis of the following: laboratory blanks, laboratory quality control samples, matrix spike samples, and duplicate samples. DWR's Bryte laboratory follows standard operating procedures to assess the accuracy and precision of all analytical procedures.

3. Sample Representativeness

Sites were selected throughout the study area in an effort to record the geographic variation in soil water SC. Sites were chosen that were subject to different management practices and covered the five major soil types. The western, central, and eastern marsh were represented.

It was impossible to thoroughly characterize the entire project area due to soil heterogeneity. Samples were collected in an attempt to represent the variability of both the vertical (top 1-foot) and horizontal soil water SC within a monitored ownership. At most sites, soil water SC was monitored in the top foot of soil, using soil water extractors installed 6-inches below the soil surface, in triplicate and approximately 12-inches apart. The accuracy of determining the average soil water SC in the top foot of soil using a single extractor at the 6-inch level was evaluated after the first year of the study. Soil water SC from the 6-inch extractors was compared with the results from extractors placed 3 inches and 9 inches deep in Reyes and Joice series soils at locations of both high and low channel water SC. Results of the comparison indicated that SC differences between the three depths were negligible, and it was assumed that water extracted from the 6-inch depth adequately represented water SC within the first foot of soil.

4. Data Limitations

There are two ways to measure soil water salinity, salt amount or salt concentration. Measurements of salt concentration (specific conductance, or SC) are inversely related to the amount of water in the soil, and the addition of water to the soil will decrease the salt concentration but not change the salt amount. Because the monitoring program was concerned with the growth of waterfowl food plants, it was decided to measure salt concentration because it more accurately expresses how the plants "experience" soil salinity.

Because the moisture content of the soil was not measured, the actual amount of salt in the soil is not known. Because SC changes with soil moisture, comparison of soil water SC between sites (or even between months at the same site) cannot be done with any accuracy. In this document, when comparing soil water SC values among sites, averages of soil water SC at each site are used in an effort to reduce the variability in the measurements due to changes in soil moisture.

Because of spatial variability in soil water salinity, there were insufficient sampling sites. Within a single meter of distance, 50% of an entire field's variability in soil salinity can occur (Corwin, personal communication; see Notes at end of chapter), so the limited number of sampling sites probably did not collect representative data for each monitored ownership.

5. Gravimetric vs. Porous Cup Extract Methods

Early studies in the Suisun Marsh measured soil electrical conductance (EC) gravimetrically, using a 1:5 gravimetric dilution extract (ECe). Mall (1969) utilized this method to develop soil SC guidelines for the Suisun Marsh. However, the 1984 Plan of Protection for the Suisun Marsh (POP) required the Department of Water Resources to measure the EC of an extract that was withdrawn directly from the soil using a porous ceramic cup (ECw). The primary concern with soil SC in the marsh is its effect on vegetation, and the ECw closely represents the SC that the plant roots experience. The POP also states the necessity to determine a relationship between the two monitoring methods. This relationship was determined in a study conducted for DWR, "*Specific Conductance Measurements in the Suisun Marsh, 1994*".

This report compares data from four different sites, gathered over 12 months. EC values for the samples were measured by both the gravimetric dilution extraction (ECe) and vacuum extraction methods (ECw). ECe was measured by preparing a gravimetric dilution of the soil sample. The soil water was then extracted from the dilution soil paste via a suction device such as a buchner funnel. The extract from which the EC is measured is called a gravimetric dilution extract. ECw was measured using porous ceramic cups installed in the soil. A pressure gradient is created in the ceramic cup, which will extract solution from the soil. The EC of the solution extracted from the porous ceramic cup is measured directly to obtain the ECw measurement.

The relationship between the two different methods was determined using linear regression. The relationship obtained is as follows:

$$ECe = 1.99 + 1.39 * ECw \qquad R^2 = 0.829$$

Various statistical methods confirmed that the errors are independent, have a zero mean, a constant variance, and follow a normal distribution. However, the following limitations must be considered when applying the relationship:

- The values of ECw must lie in the domain of the data used to develop the equation, 5 to 40 mS/cm. Extrapolation using values beyond this is not recommended.
- The equation is limited to Suisun Marsh soils.

For purposes of this Comprehensive Review, the ECw values will be used to represent soil SC, or salt concentration. These values closely represent the salinity that the plant roots are experiencing, which is the primary concern.

B. Data Results

This section does not include discussion of the data collected at sites 5, Family Club or sites 50 and 51, Sunrise Club. These data were not used because these three sites were monitored for only a short time, and did not contribute to the long term data analysis. Most of the soil water salinity data discussed below is from a depth of 6 inches below the surface. At four sites, soil tubes collected water from three depths; 6, 18 and 30 inches. These data are discussed below in section B-7.

There are many factors that affect soil water SC, including water management (timing and duration of fill and drain, circulation, leaching), precipitation, SC of applied water, soil type, and water year type (both current and previous year). Because there were no controlled studies to look at each of these factors individually, it was not possible to quantify the effect of any single factor.

The effects of water management activities on soil water SC are discussed in Chapter XI, Management.

1. Soil Water Specific Conductance Temporal Trends

Monthly soil water SC values for the sites at each monitored ownership are graphed in figures VI-1 through VI-12. Because monthly fluctuations can mask long term trends in soil water SC, trends were assessed using averages of monthly soil water SC values. Average soil water SC for January through June of each water year is plotted in figures VI-13 through VI-24. As with the pond water evaluation, only the months of January through June were used, because they represent the period of water management and include the months critical to plant growth.

Regression analysis was performed to determine if there was a significant linear trend in SC at each site over the study period. This analysis does not infer a causal relationship between time and SC, and was used only to evaluate linear trends in soil water SC over time. Soil water SC was considered to show a definite linear trend over the monitoring period if the coefficient of determination, or R^2 value, was equal to or greater than 0.8. Sites with R^2 values less than 0.8 were not considered to have a significant linear trend over the entire monitoring period, but may show trends for portions of the study period.

As with the pond water SC temporal trends, the majority of the soil water sites had fluctuating SC over the monitoring period, with no discernable linear trend or pattern. Thirteen of the 49 sites, approximately 25%, had R^2 values of 0.8 or greater, indicating a significant increasing trend over the study period (sites 2 and 4 on Morrow Island, Figure VI-13; sites 6, 8, and 10 on Tule Belle, Figure VI-14; site 11 on Teal, Figure VI-15; sites 15 and 16 on Joice Island, Figure VI-16; sites 25 and 26 on Gum Tree, Figure VI-18; and sites 32, 34, and 35 on Sprig, Figure VI-20). It is important to note that the sites showing increasing trends were all located in ponds that had other monitoring sites without increasing trends in soil water SC. From the data collected in the monitoring program, this cannot be directly explained, but possibilities are discussed in later sections of this chapter.

No site had a definite decreasing or stable trend over the entire study period; however, decreasing trends were discernable over portions of the study period. Regression analysis of the 1993-1995 data show that most sites had a decreasing linear trend following the 1987-1992 drought (Figure VI-25). Trends in soil water SC for individual monitored ownerships are discussed in general below and more specifically in the appendices.

To provide a general indication of soil water SC trends in the marsh from 1985 to 1995, January to June soil water SC values from all sites were lumped together and averaged for each year (Table VI-1). As can be seen in the table, the average marsh-wide soil water SC increased in 1986, and in 1987, the beginning of six years of drought (dry or critical water years). The increase in 1986, a wet year, is probably due to high applied water SC in the first two months of the water year, October and November 1985. Marsh-wide soil water SC decreased in 1994, which was one year after an above-normal water year. It is not known why soil water SC increased in 1987, which also followed a wet year. These results indicate that sometimes there is a lag in response of soil water SC to changes in applied water SC, but the inconsistency of the data suggest that other factors exert significant influence on soil water SC.

Table VI-1 Marsh-wide ranges and averages of January-June soil water salinity averages in mS/cm.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
N=*	41	45	44	47	47	47	35	18	9	8	9
Avg of Jan-June avgs	14	21	28	25	28	25	28	31	29	22	21
Range	5-31	10-51	8-64	14-53	12-53	8-57	11-60	12-58	20-43	10-41	7-41

*yearly data sets for sites with less than 3 data points were dropped, and site 9 was not included due to it's abnormally high soil water salinity.

In general, the annual soil water SC (January to June average) on most ownerships increased from 1985 to 1989 or 1990 and then stayed somewhat stable until the end of the monitoring period (1992 in most cases). This general pattern was evident at Grizzly Island, Sprig, Joice Island, Morrow Island, and Teal. Mallard, Gum Tree, Island Club, and West Family increased annually until 1987 or 1988, and then decreased (West Family) or fluctuated (Mallard, Gum Tree, Island) through the rest of the monitoring period. Sites on Tule Belle generally increased until 1991, after which the one remaining site decreased through 1995. The site on Goodyear was stable during 1985 and 1986, increased 100% in 1987, then stayed relatively stable through 1995. Grizzly King showed a steady increase in SC from 1985 to 1992 with a minor drop in SC in 1990.

The trend of increasing soil water SC from 1985 until about 1989 was recorded at most soil tube sites in the monitoring program, and is probably due to drought conditions. The

SC of channel water used to flood the ponds in October increased from about 7 mS/cm in water year 1987 to about 18 mS/cm in water year 1989 (stations S49, S54, and S33). It seems that these years of very high applied water SC had a lasting effect on soil water SC. Even ownerships that engaged in active water management, such as West Family, were unsuccessful at preventing soil SC increases from 1985 to 1989.

Despite drought conditions that persisted from 1987 to 1992, applied, pond, and soil water SC at many recording stations declined in 1990. The operation of the Suisun Marsh Salinity Control Gates beginning in 1989 resulted in lowered channel and pond water SC and may explain the consequent decline in soil water SC on many ponds. Control Gate operations appeared to offset the effects of the drought and may have prevented further accumulation of solutes in soils on most ponds.

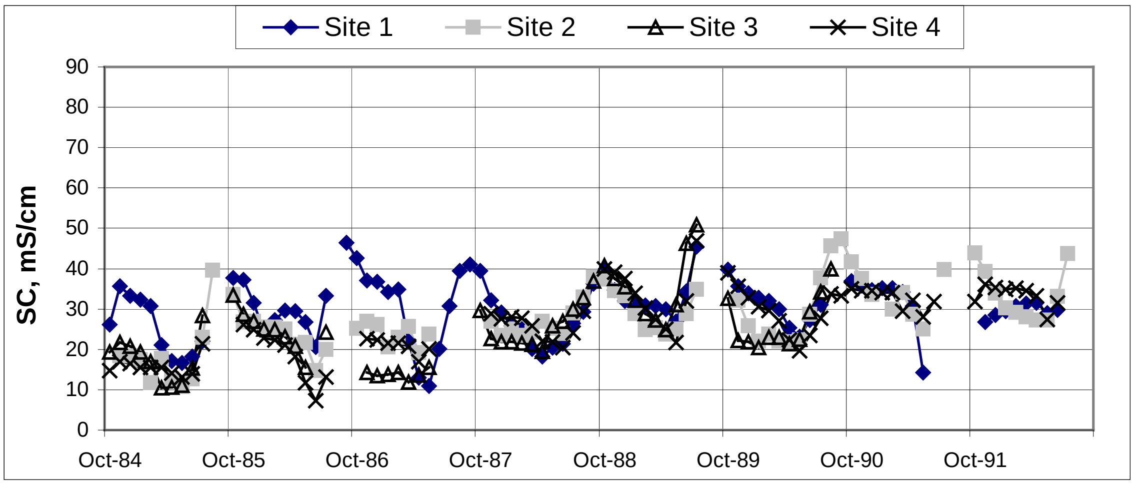


Figure VI-1. Monthly soil water SC at Morrow Island, WY85-92.

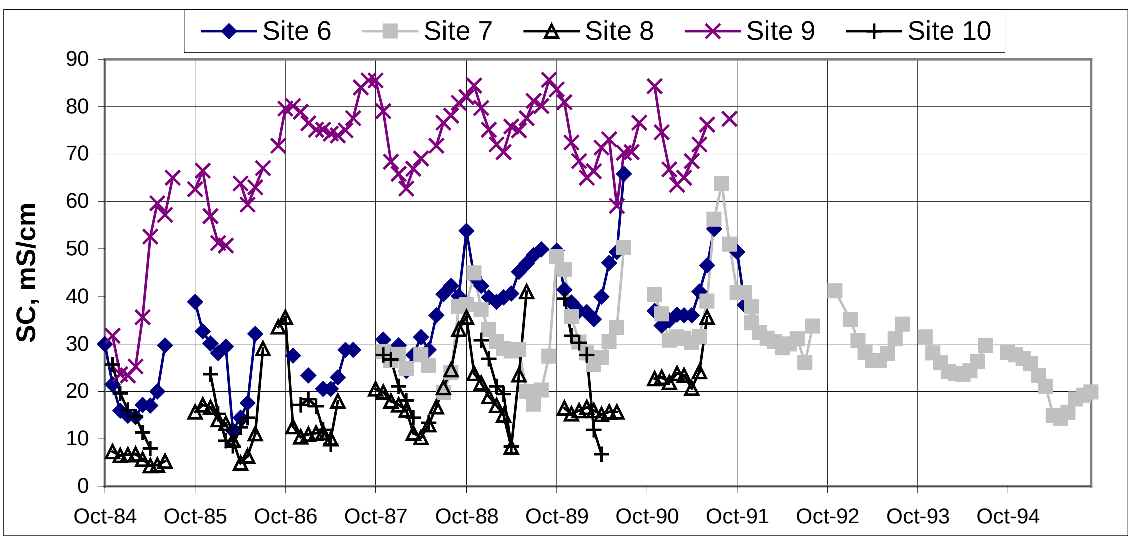


Figure VI-2. Monthly soil water SC at Tule Belle, WY85-95.

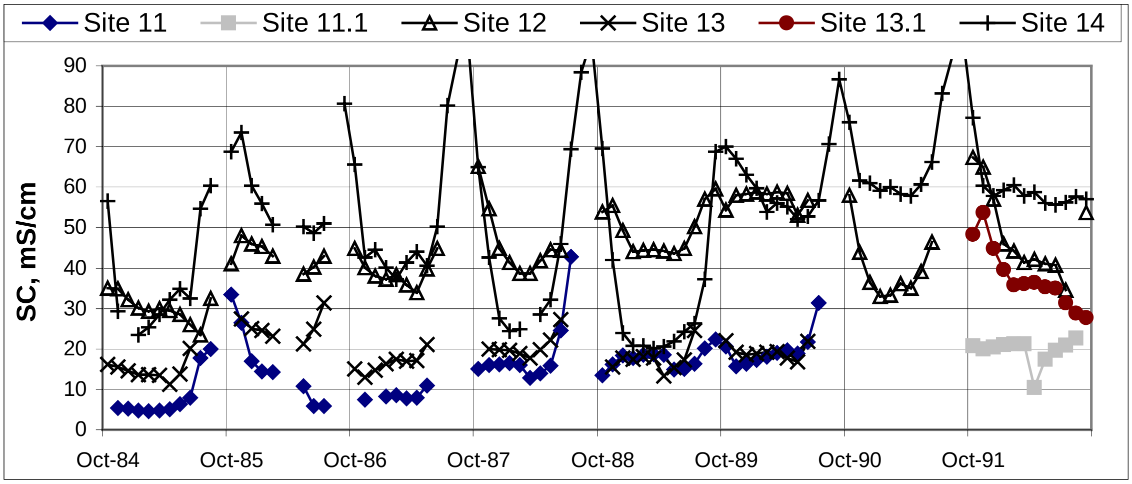


Figure VI-3. Monthly soil water SC at Teal, WY85-92.

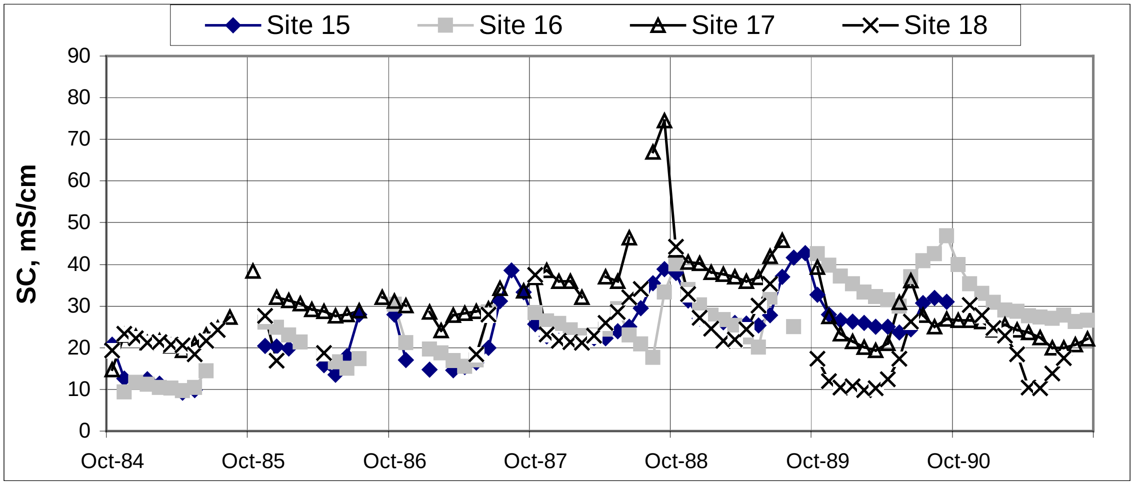


Figure VI-4. Monthly soil water SC at Joice Island, WY85-91.

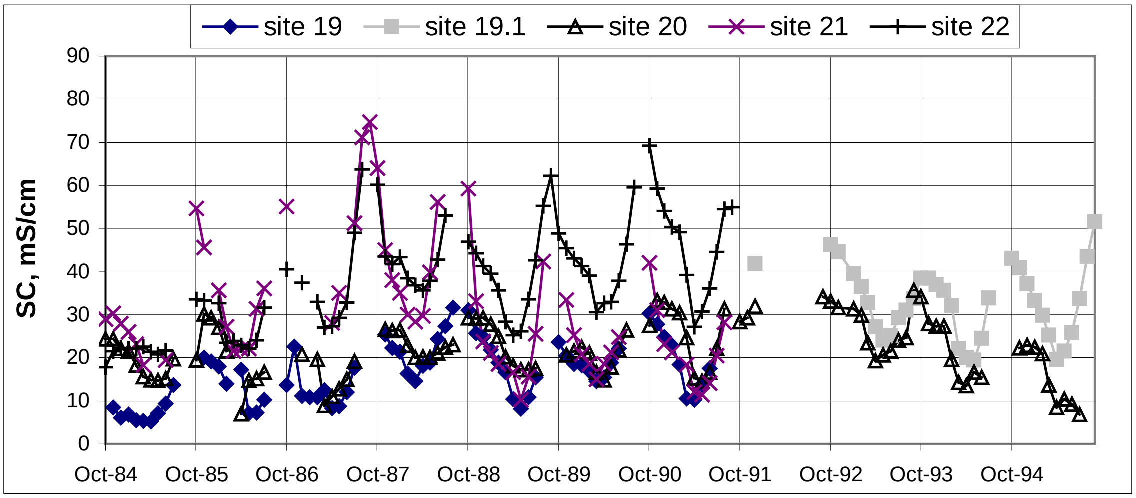


Figure VI-5. Monthly soil water SC at Island Club, WY85-95.

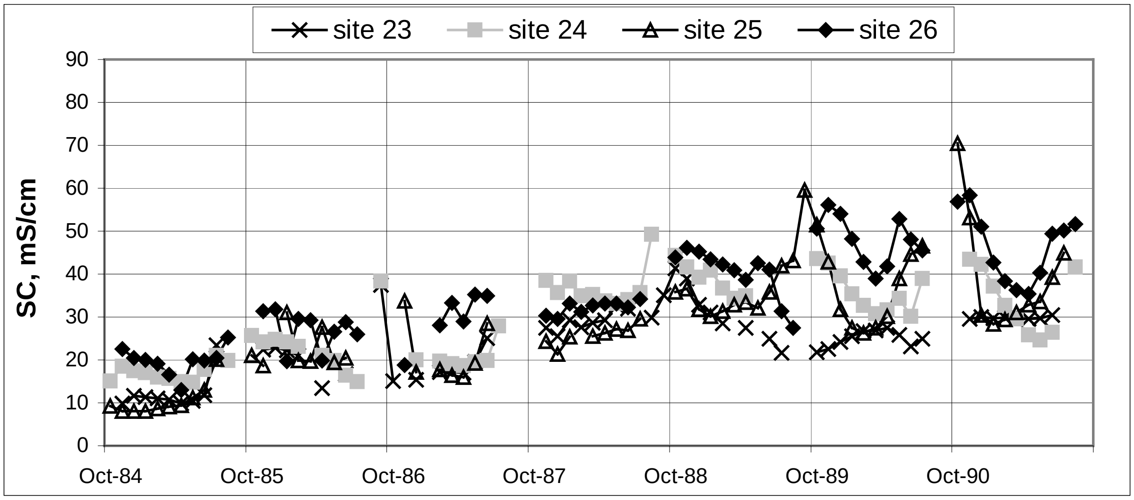


Figure VI-6. Monthly soil water SC at Gum Tree, WY85-91.

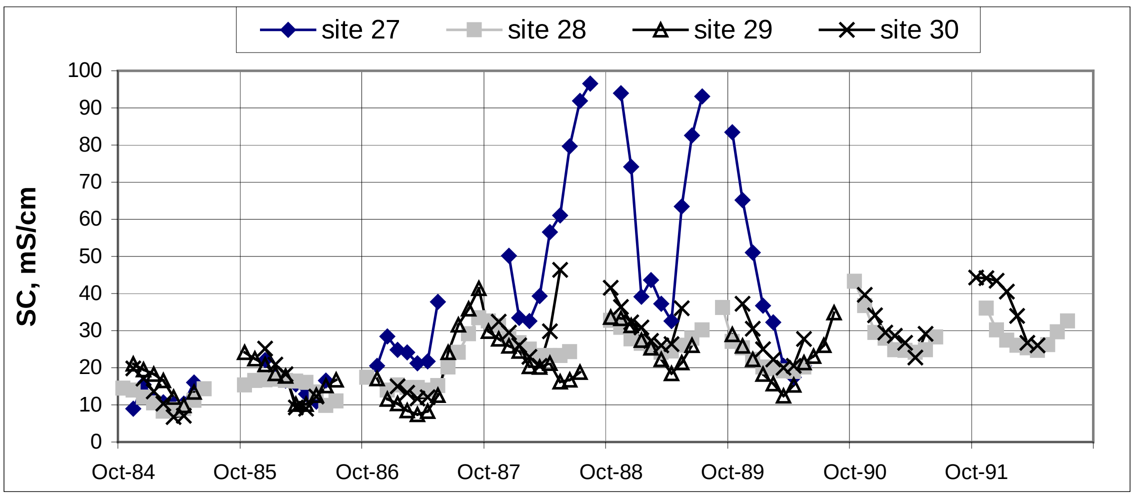


Figure VI-7. Monthly soil water SC at Grizzly King, WY85-92.

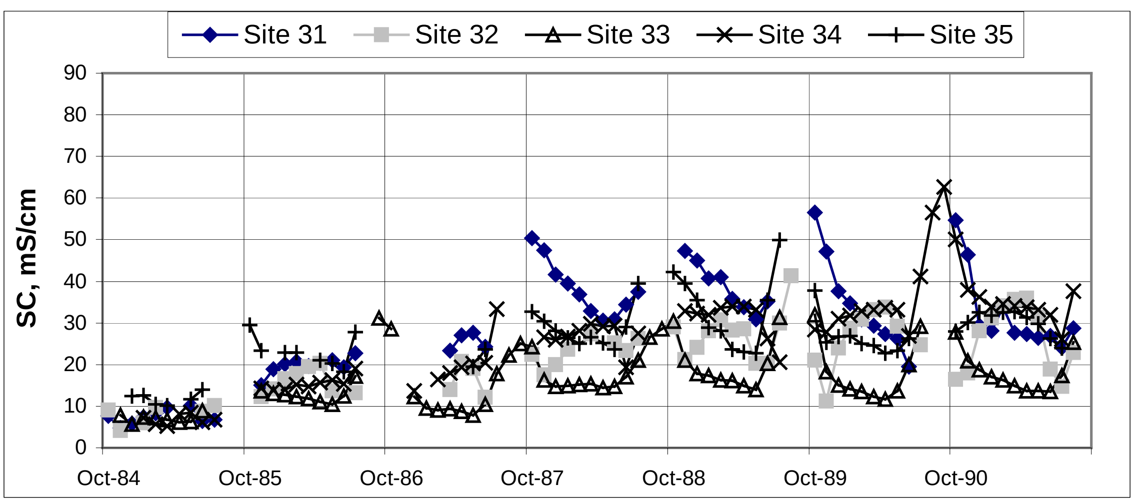


Figure VI-8. Monthly soil water SC at Sprig Farms, WY85-91.

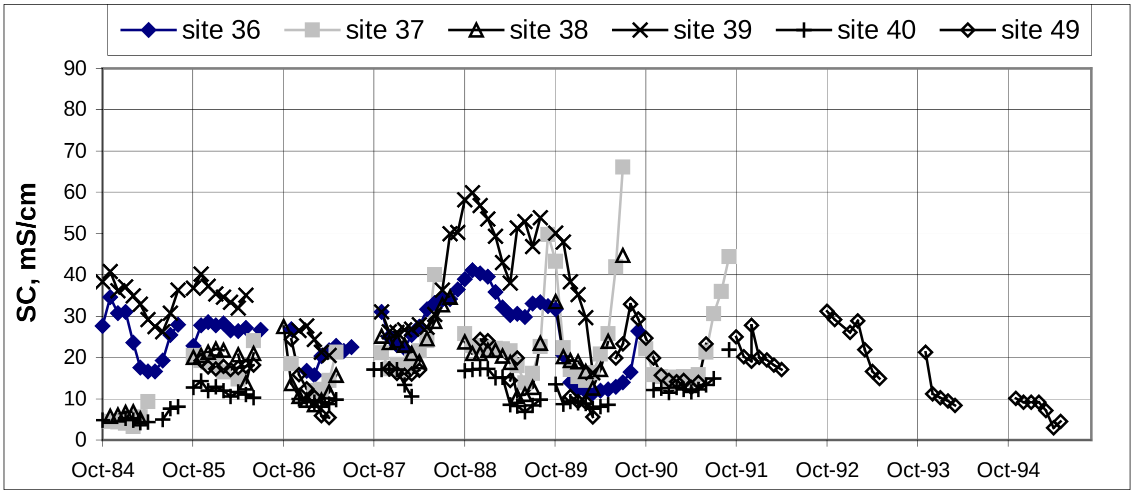


Figure VI-9. Monthly soil water SC at Grizzly Island, WY85-95.

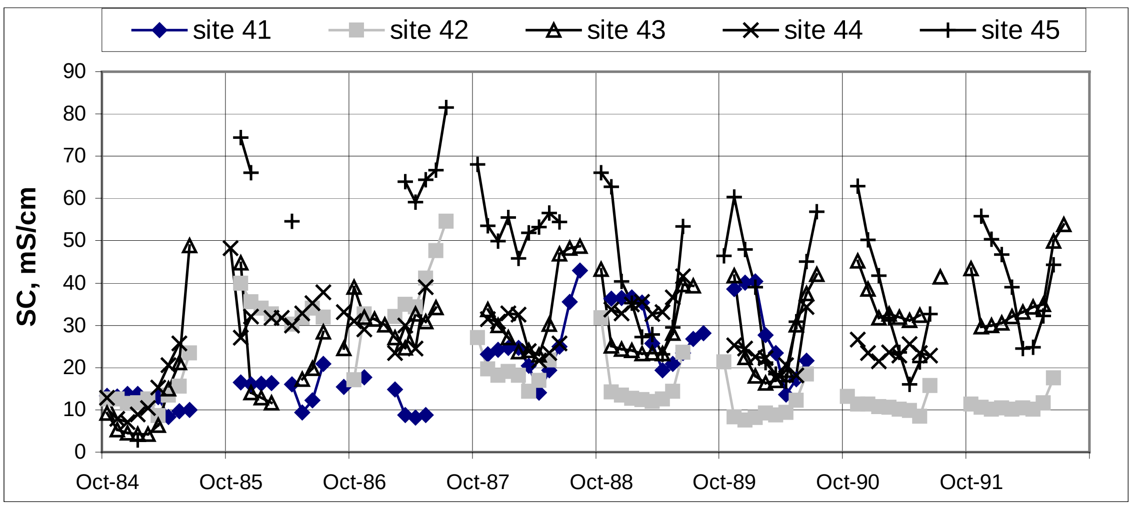


Figure VI-10. Monthly soil water SC at Mallard, WY85-92.

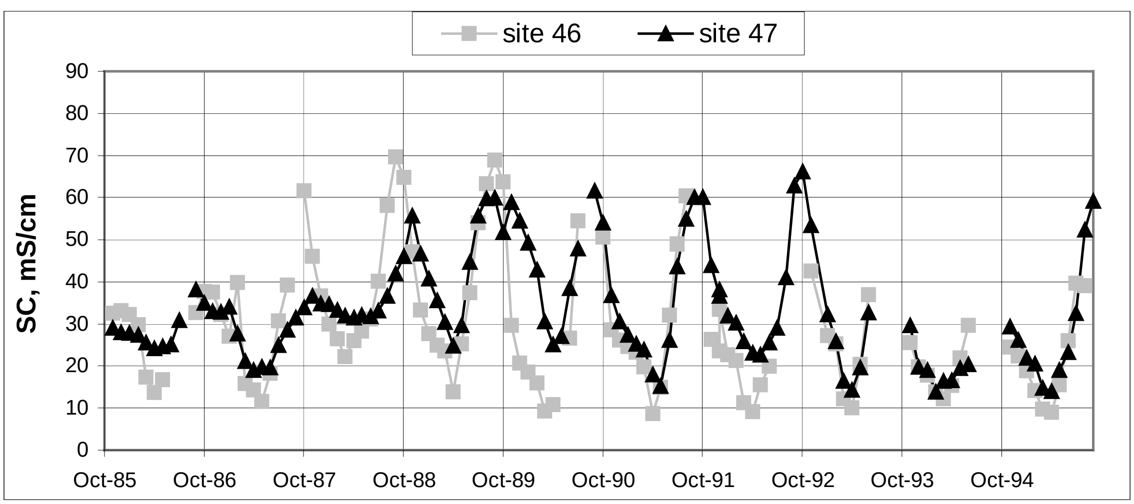


Figure VI-11. Monthly soil water SC at West Family, WY86-95.

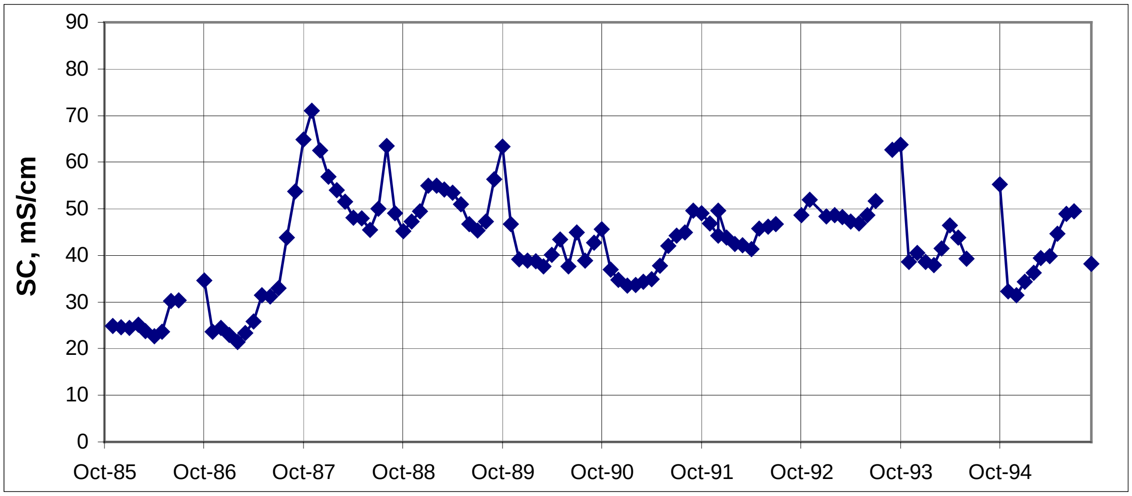


Figure VI-12. Monthly soil Water SC at Goodyear Site 48, WY86-95.

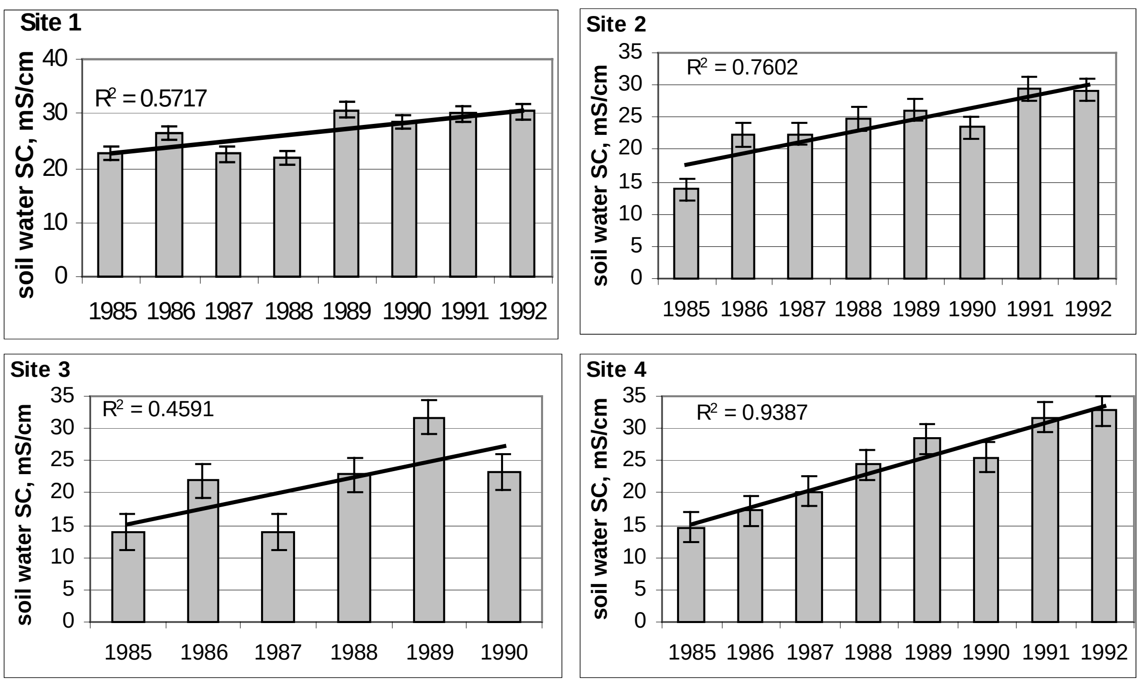


Figure VI-13. Trends in annual average (Jan-June) soil water SC at Morrow Island sites 1-4, WY85-92. Error bars denote one standard error.

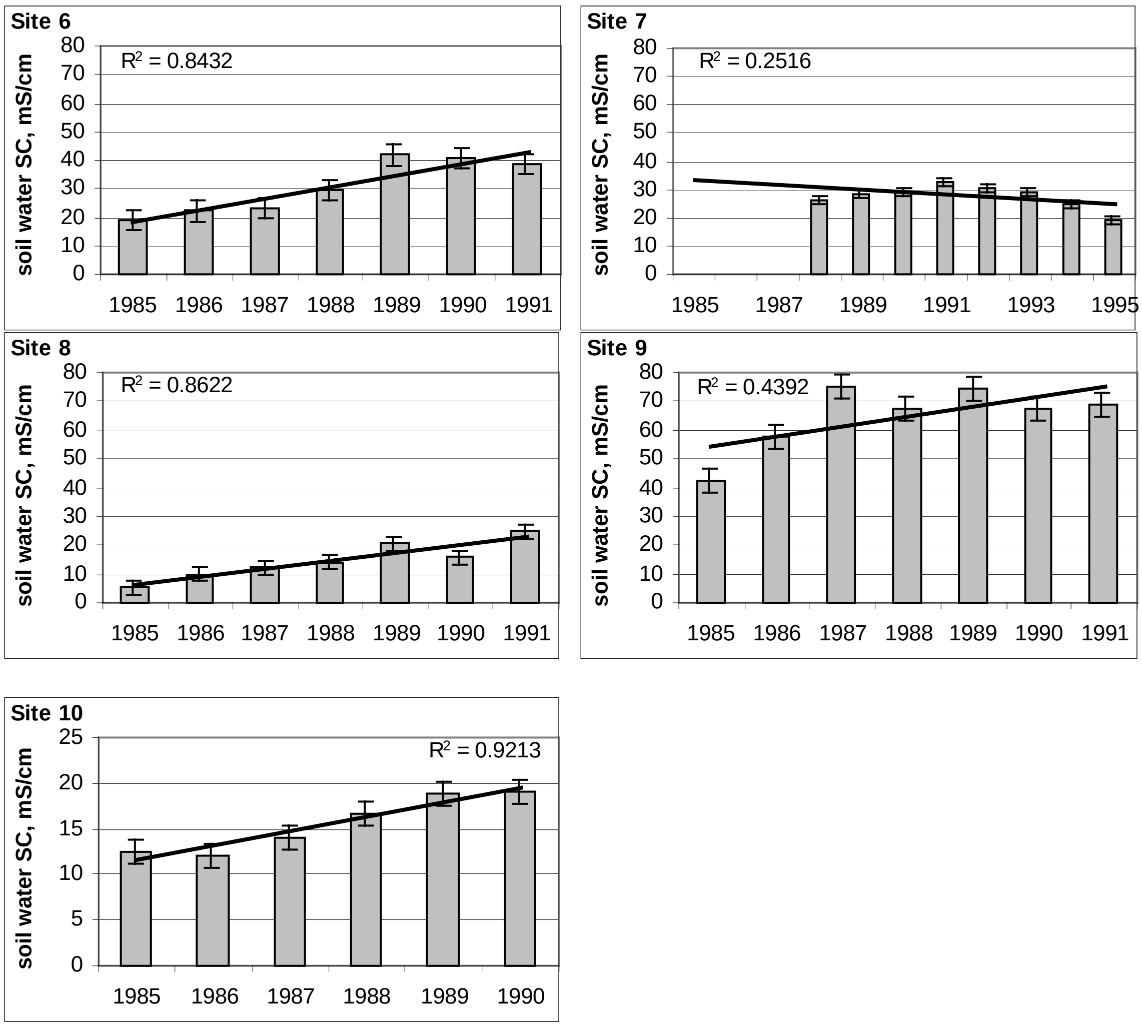


Figure VI-14. Trends in annual average (Jan-June) soil water SC at Tule Belle sites 6-10, WY85-95. Error bars denote one standard error.

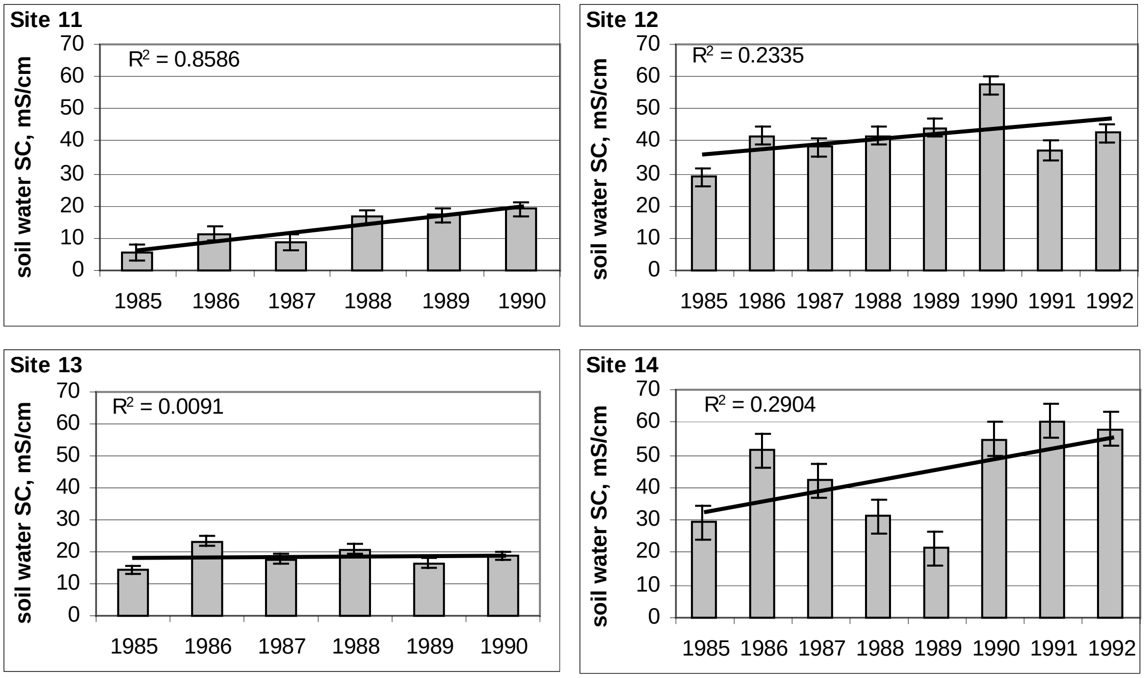


Figure VI-15. Trends in annual average (Jan-June) soil water SC at Teal sites 11-14, WY85-92. Error bars denote one standard error.

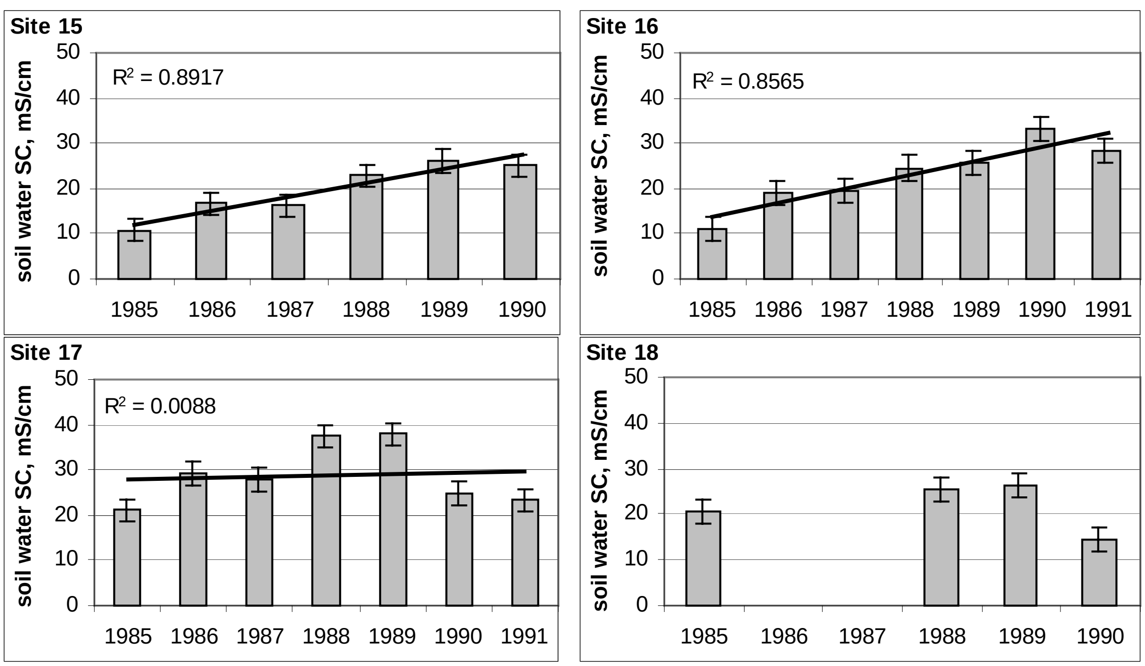


Figure VI-16. Trends in annual average (Jan-June) soil water SC at Joice Island sites 15-18, WY85-91. Error bars denote one standard error.

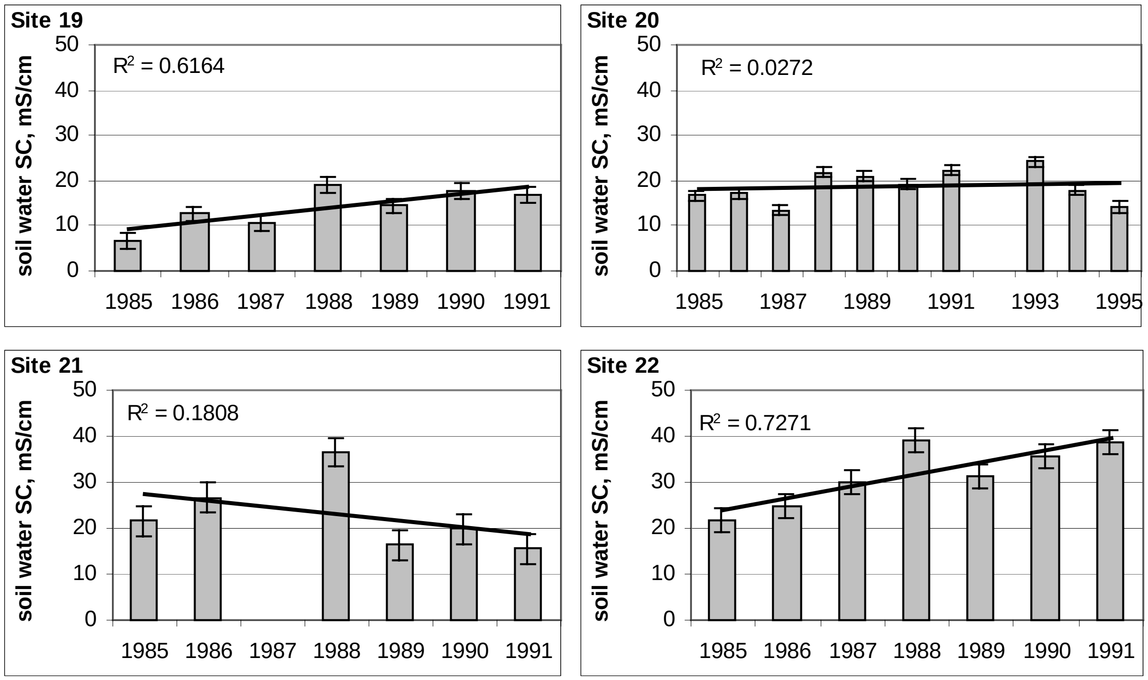


Figure VI-17. Trends in annual average (Jan-June) soil water SC at Island Club sites 19-22, WY85-95. Error bars denote one standard error.

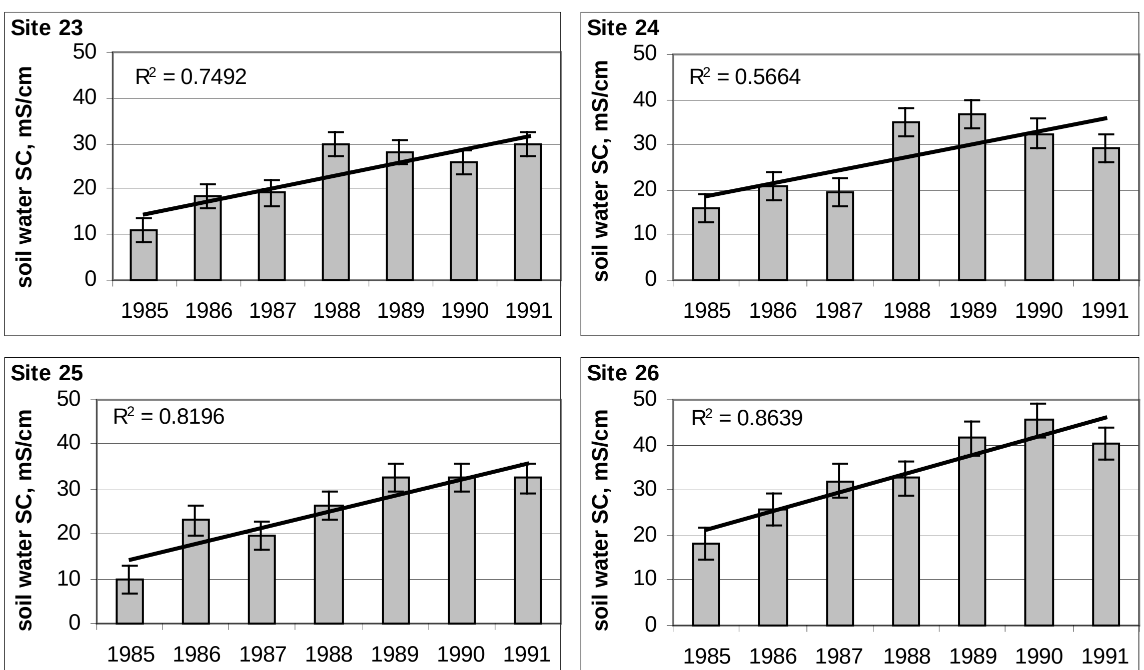


Figure VI-18. Trends in annual average (Jan-June) soil water SC at Gum Tree sites 23-26, WY85-91. Error bars denote one standard error.

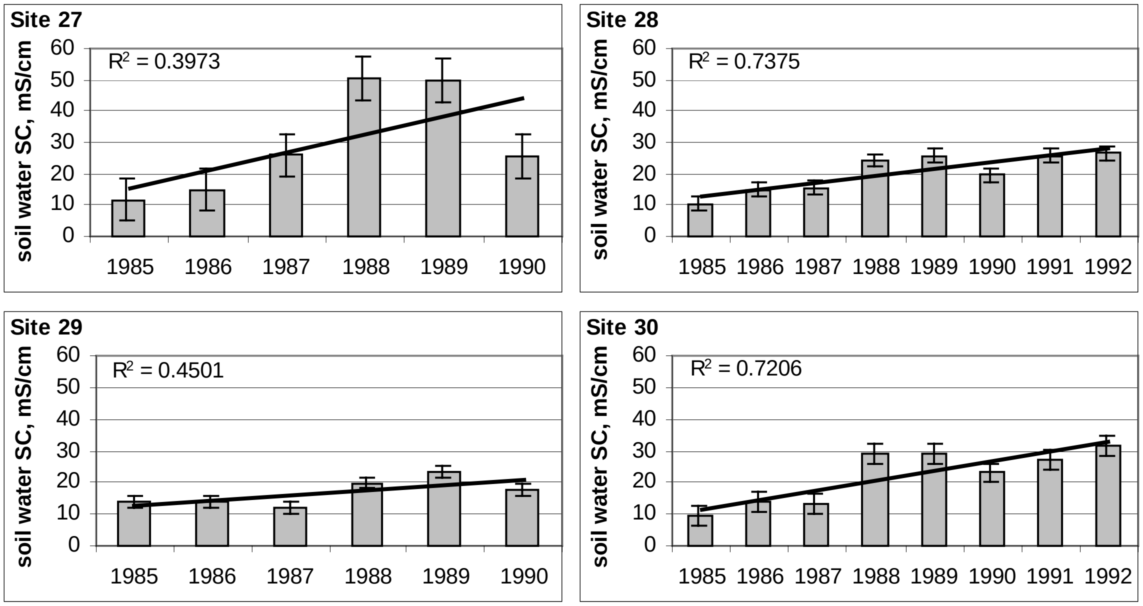
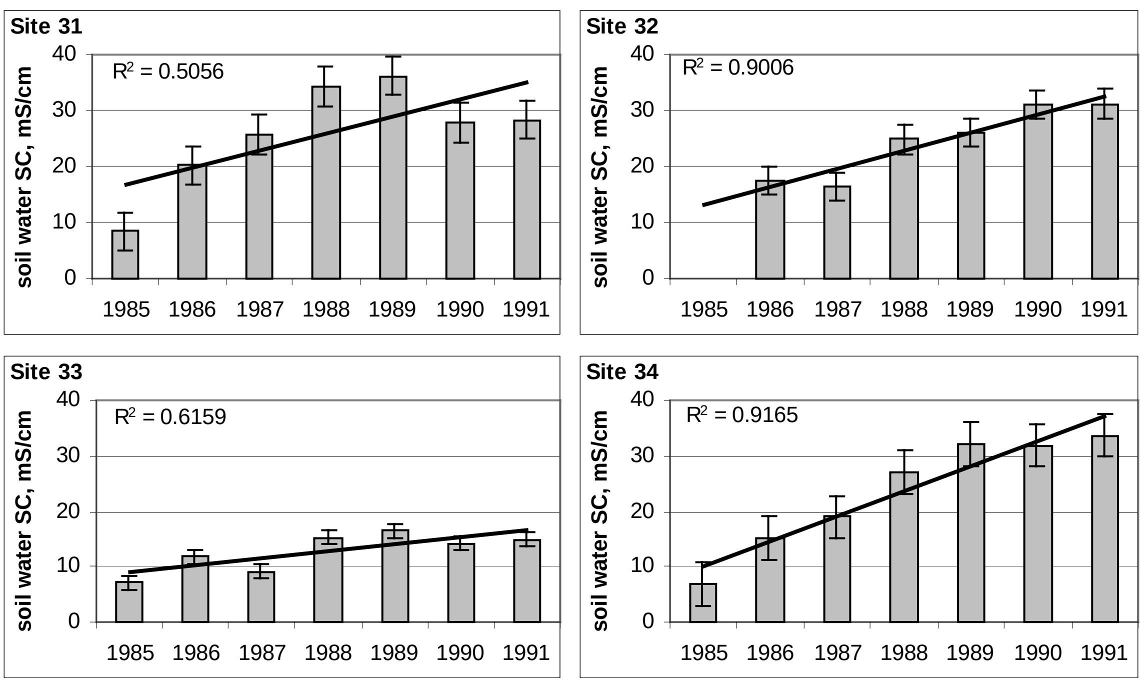


Figure VI-19. Trends in annual average (Jan-June) soil water SC at Grizzly King sites 27-30, WY85-92. Error bars denote one standard error.



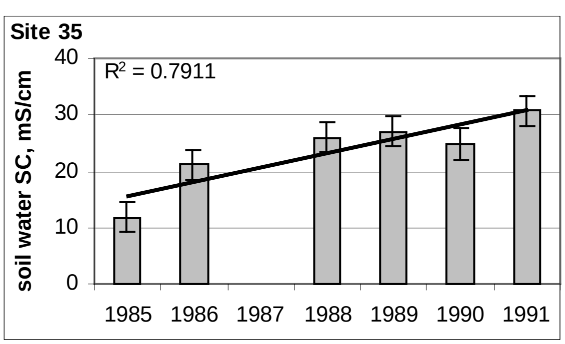


**Figure VI-20. Trends in annual average (Jan-June) soil water SC at Sprig sites 31-35, WY85-91.
Error bars denote one standard error.**

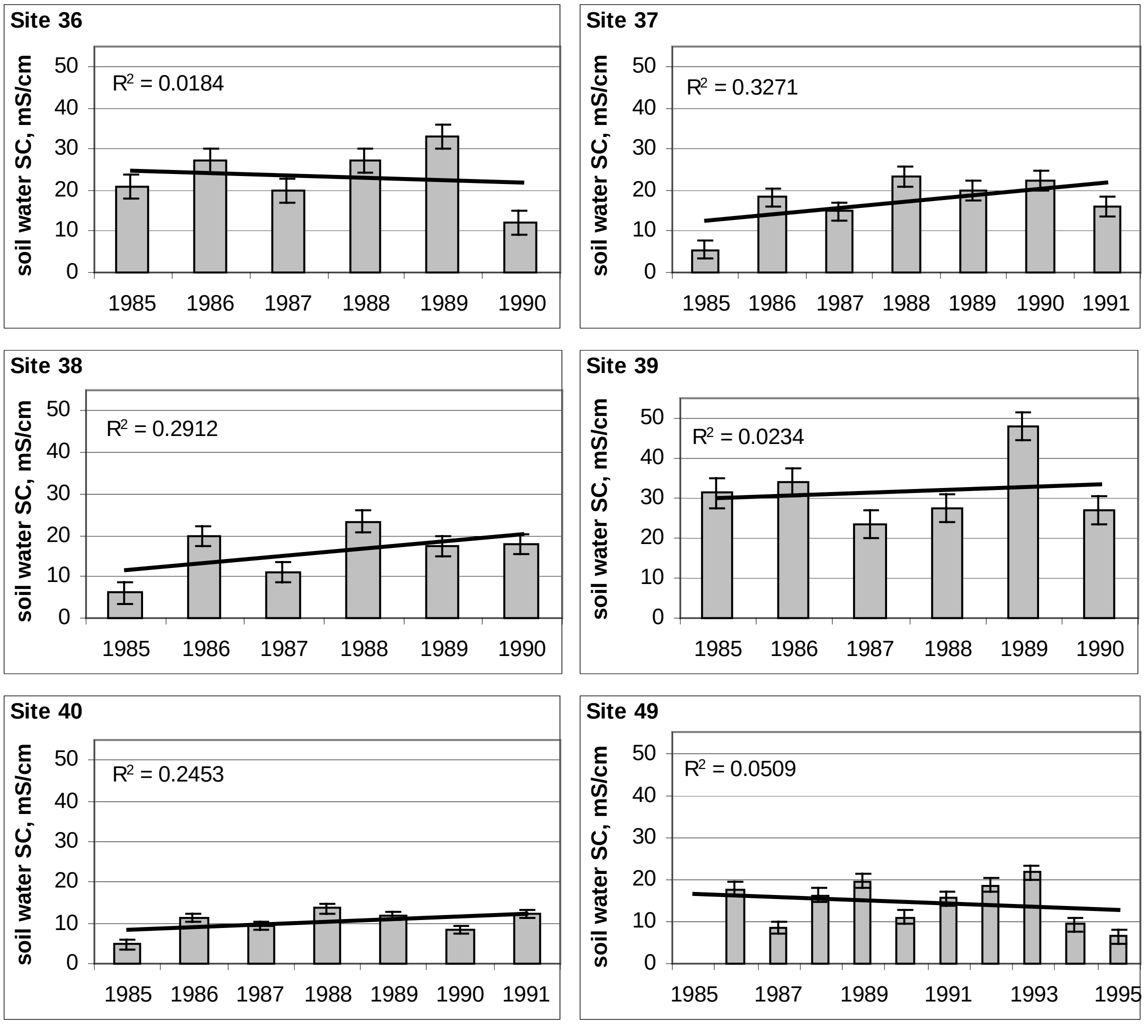
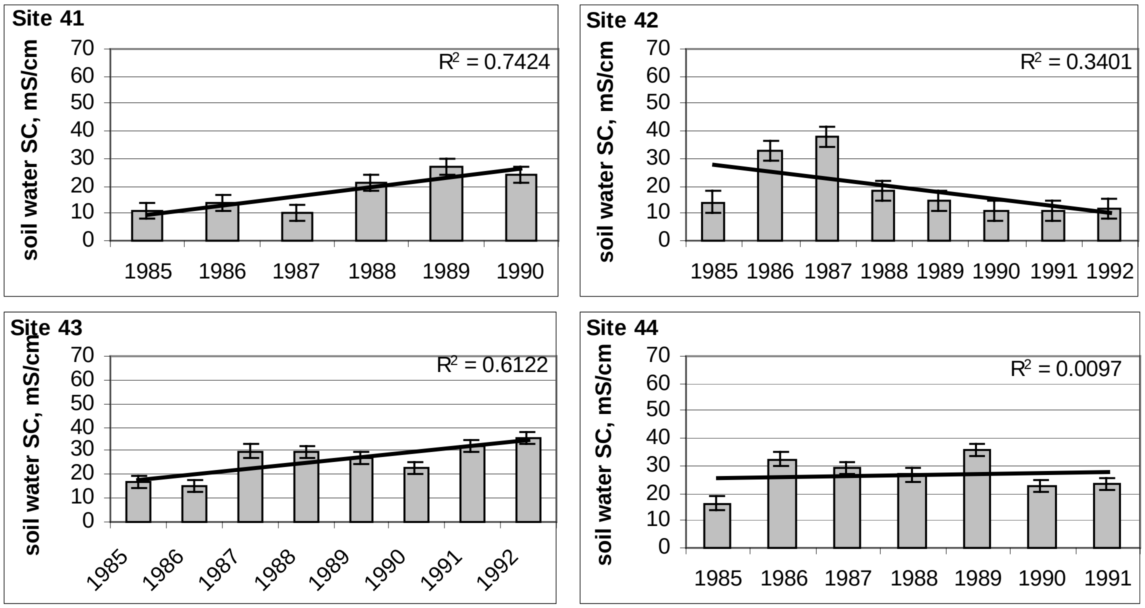


Figure VI-21. Trends in annual average (Jan-June) soil water SC at Grizzly Island sites 36-40 and 49, WY85-95.   Error bars denote one standard error.



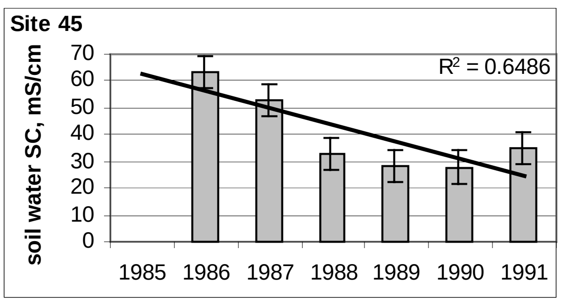


Figure VI-22. Trends in annual average (Jan-June) soil water SC at Mallard sites 41-45, WY85-92.
Error bars denote one standard error.

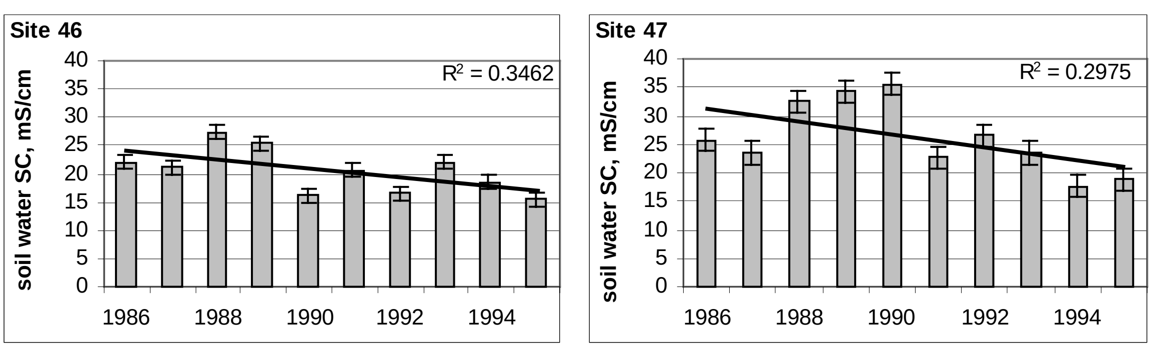


Figure VI-23. Trends in annual average (Jan-June) soil water SC at West Family sites 46 and 47, WY86-95. Error bars denote one standard error.

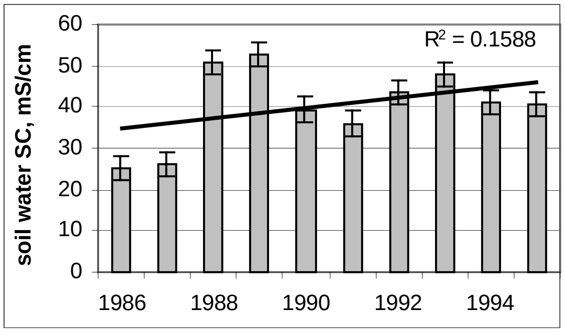


Figure VI-24. Trends in annual average (Jan-June) soil water SC at Goodyear Site 48, WY86-95. Error bars denote one standard error.

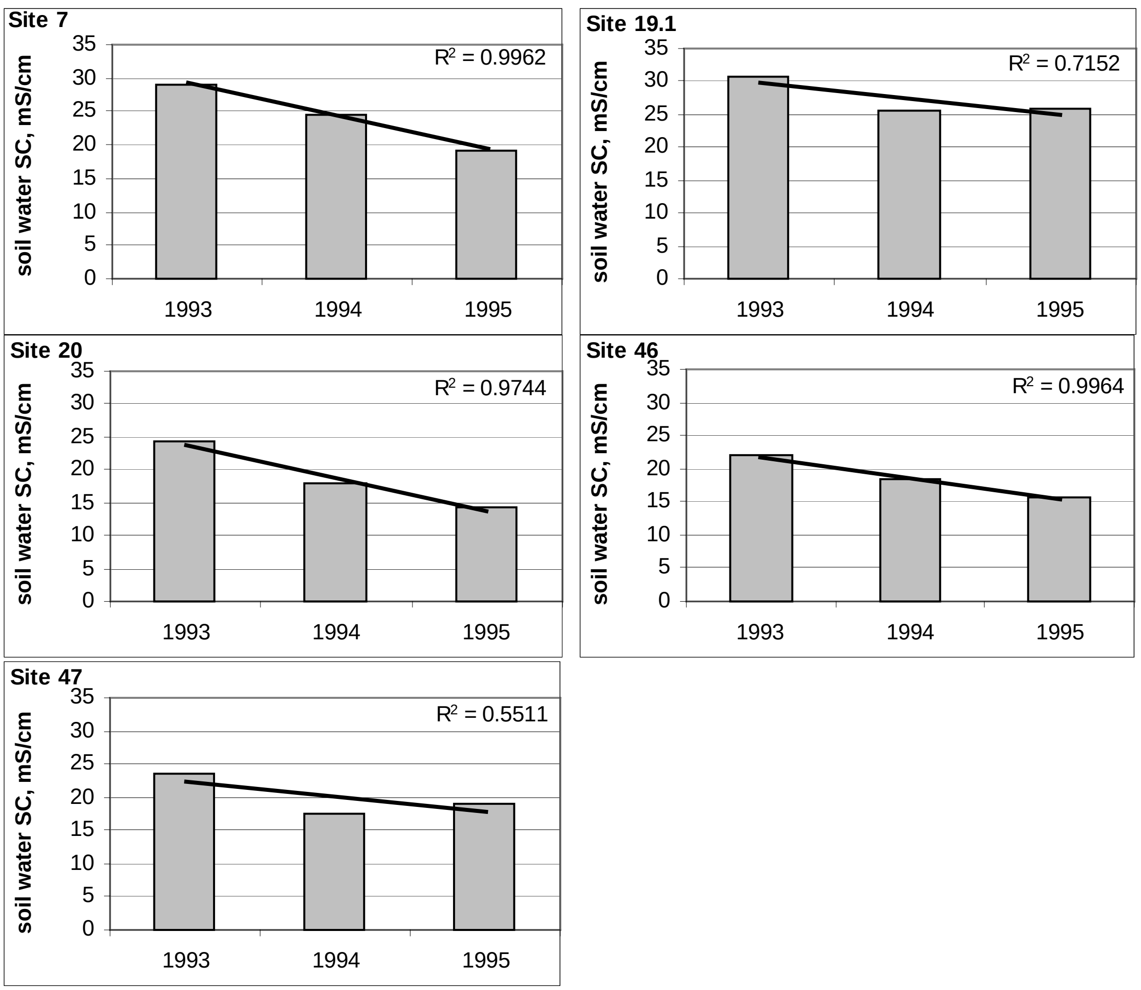


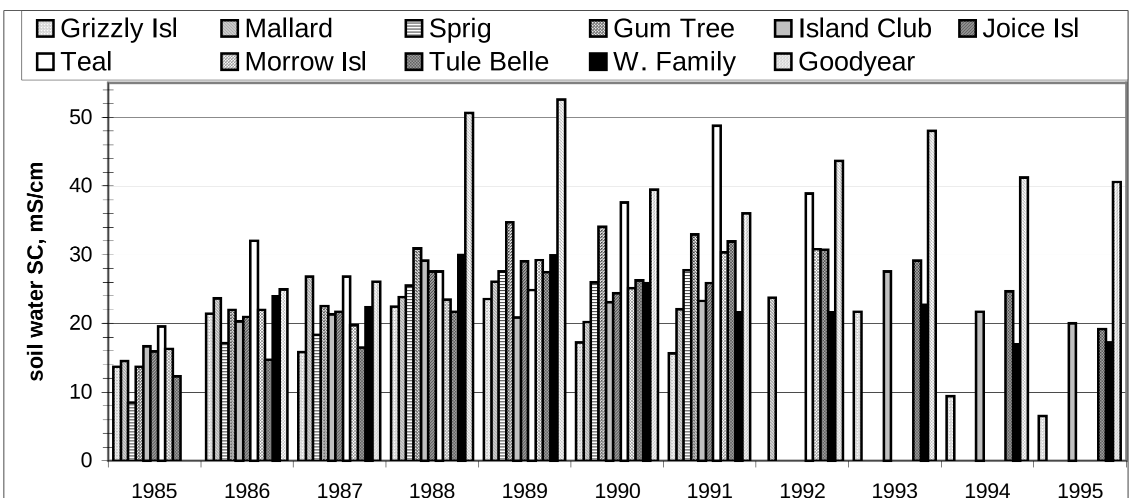
Figure VI-25. Trends in annual average (Jan-June) soil water SC from WY93 to WY95. Error bars denote one standard error.

2. Spatial Trends in Soil Water Specific Conductance

There was a great deal of variability in soil water SC values between sites on the same ownership. The analyses below show that there was no clear-cut relationship between location in the marsh and soil water SC values. Because channel water SC is lower in the eastern marsh, it was expected that soil water SC would also be lower, but it appears that management and site variability may play a greater role in determining soil water SC in managed wetland sites.

To determine if there were spatial trends in soil water SC, two analyses were done. First, January-June soil water SC averages for all sites on each ownership were plotted in order from east to west for each year (Figure VI-26). The figure illustrates that soil water SC was spatially variable. The least variability was seen in water years 1985 and 1986. Water year 1985 was a dry year following a wet year, and water year 1986 was wet. Beginning in 1987 (a critical year) soil water SC became more variable, with Teal or Goodyear (both in the western marsh) generally having the highest soil water SC. Neither Teal nor Goodyear were actively managed. West Family, which was intensively managed, always had the lowest soil SC of the western ponds, and often had lower SC than one or more eastern ponds.

The second analysis examined annual soil water SC averages (January to June) for all sites over the monitoring period. These values were ordered by increasing soil water SC. Annual soil water SC averages ranged from 5 to 75 mS/cm, and sites in the eastern marsh comprised 30% of the total number of data points. However, eastern marsh sites made up 58% of the data points with annual soil water SC less than 10 mS/cm, and only 9% of the sites over 40 mS/cm. Therefore it appears that eastern marsh sites tend to have lower soil water SC than western marsh sites.



Note: Mallard does not include site 45 and Tule Belle does not include site 9, as these sites were not representative of conditions on the ownership.

Figure VI-26. Annual average (Jan-June) soil water SC with monitored ownerships in order from east to west.

3. Relationship between Applied and Soil Water Specific Conductance
As discussed above, changes in applied water SC can directly affect soil water SC, though there is sometimes a one-year lag in response. It is apparent that the drought from 1987-1992 was largely responsible for increases in soil water SC during that time. However, the widely variable soil water SC response during these years indicates that other factors, such as water management (see Chapter XI, Management), can mitigate some of the effects of applied water SC.

Monthly soil water and applied water SC are graphed together for the monitoring period in the appendices. In general, soil and applied water SC values are closest in the spring after water management activities, such as circulation and leaching, have removed some of the salts that accumulated in the soil when the pond was dry the previous summer. When ponds are dry, the soil SC is often 30-50 mS/cm greater than that of the channel water, and this disparity continues into the first month or so following flood-up in September or October.

January - June soil water SC averages for all water years were compared to the applied water SC averages. The relative percent difference (RPD) between the applied water SC average and the soil water SC average was computed to evaluate changes in the soil water SC with respect to applied water SC (Figures VI-27 to VI-38). Several of the monitored ownerships showed relatively stable RPDs from water year to water year. Morrow Island (Figure VI-27), Joice Island (Figure VI-30), Grizzly King (Figure VI-33), and West Family (Figure VI-37) had RPDs that generally stayed within 250% over the study period. Island Club (Figure VI-31) and Gum Tree (Figure VI-32) were also fairly stable, with a few exceptions. Tule Belle (Figure VI-28), Sprig (Figure VI-34), Grizzly Island (Figure VI-35), and Goodyear (Figure VI-38) showed greater fluctuations, in some cases as much as 1,250% RPD. Not enough data are available for Mallard (Figure VI-36) to determine any trends. All monitored ownerships with water year 1993 and 1995 data showed increased RPD for those years. RPD values increased to as high as 2,100% during this time period. This is due to the decreased channel water SC for these water years (Table II-3) and a lag in soil water SC response to decreased applied water SC. As with the applied water/pond water RPDs during 1993 (as discussed in Chapter 4), West Family had the lowest applied water/soil water RPD (514 at site 46 and 487 at site 47) during the 1993 water year (Figure IV-37). This indicates that at West Family the soil water SC followed the change in applied water SC more closely than at other monitored ownerships. Again, it should be noted that West Family consistently practiced intensive water management.

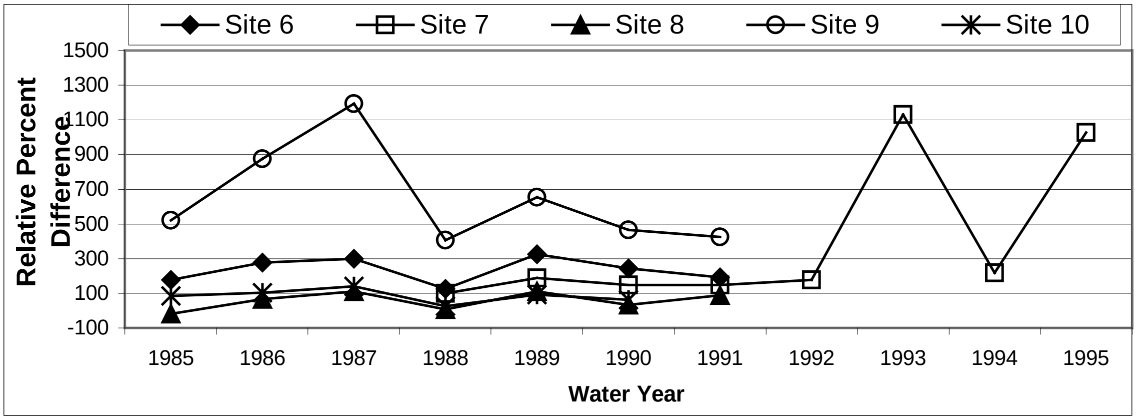


Figure VI-27. Relative percent difference between soil water SC and applied water at Morrow Island (January - June average).

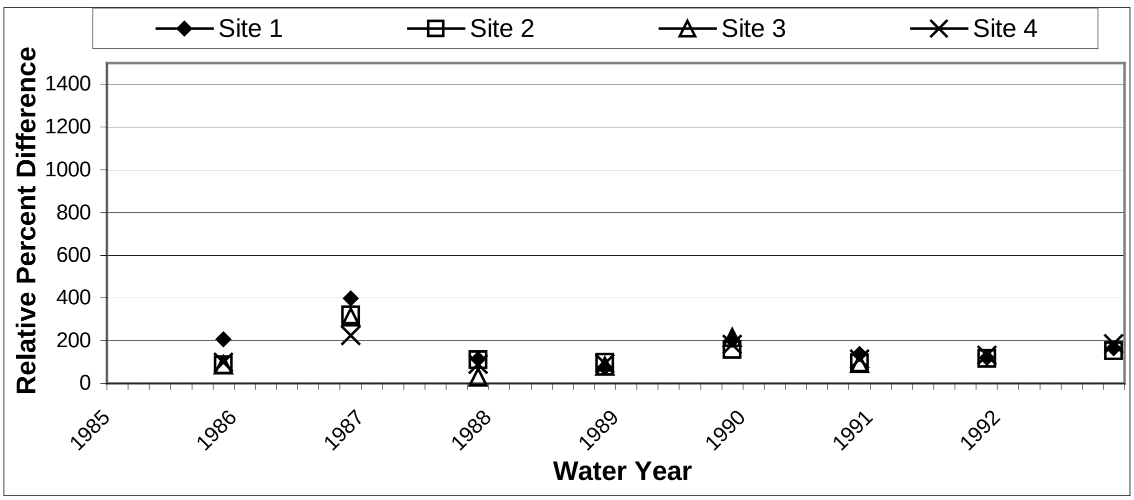


Figure VI-28. Relative percent difference between soil water SC and applied water at Tule Belle (January - June average).

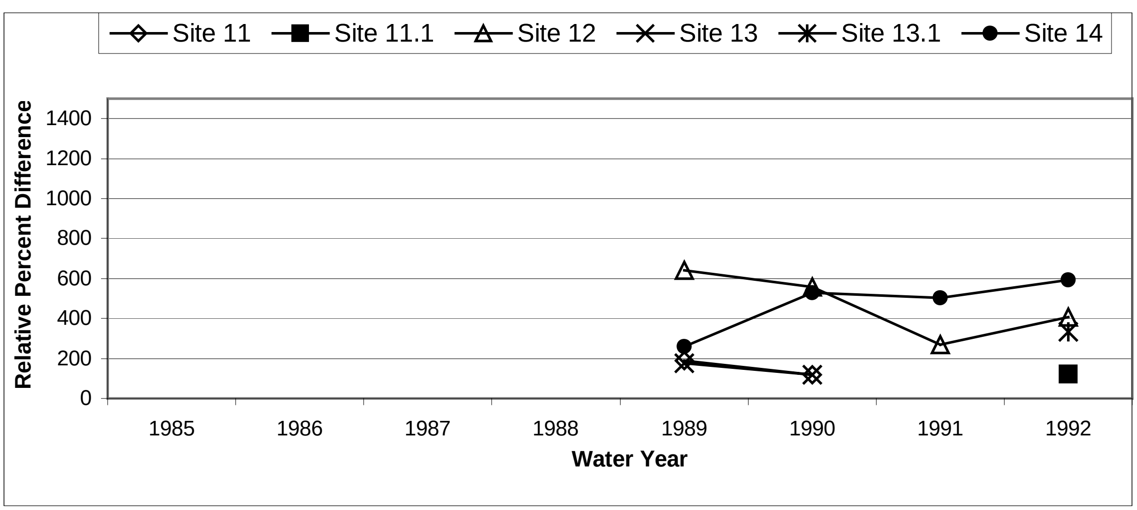


Figure VI-29. Relative percent difference between soil water SC and applied water at Teal (January - June average).

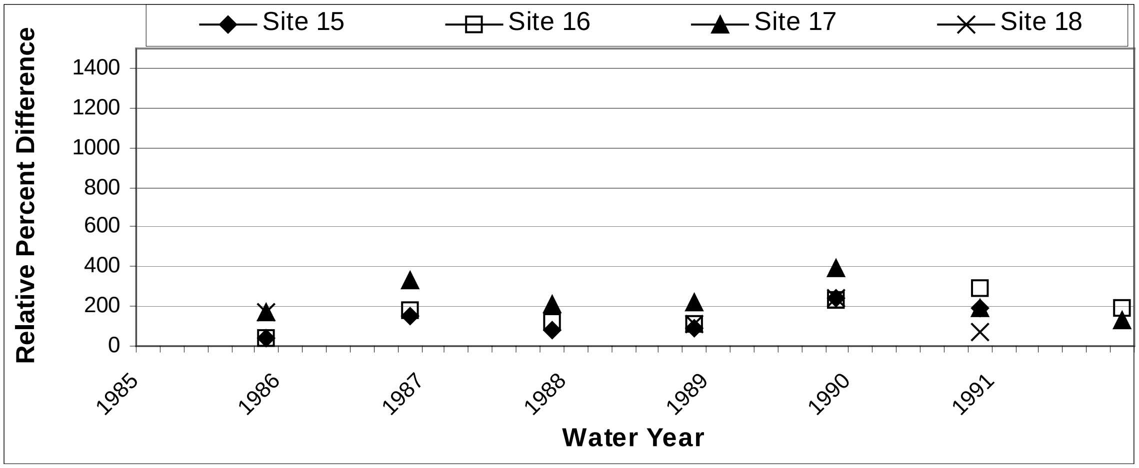


Figure VI-30. Relative percent difference between soil water SC and applied water at Joice Island (January - June average).

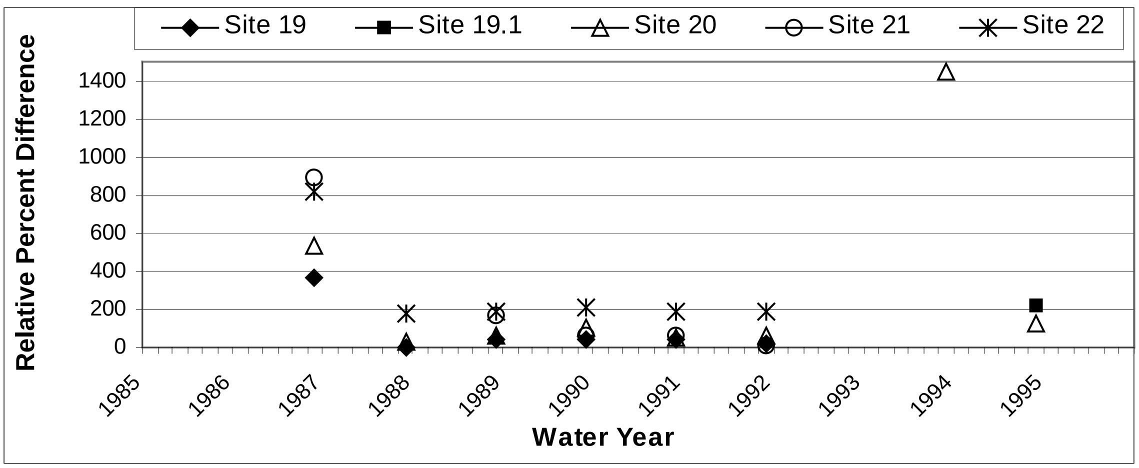


Figure VI-31. Relative percent difference between soil water SC and applied water at Island Club (January - June average).

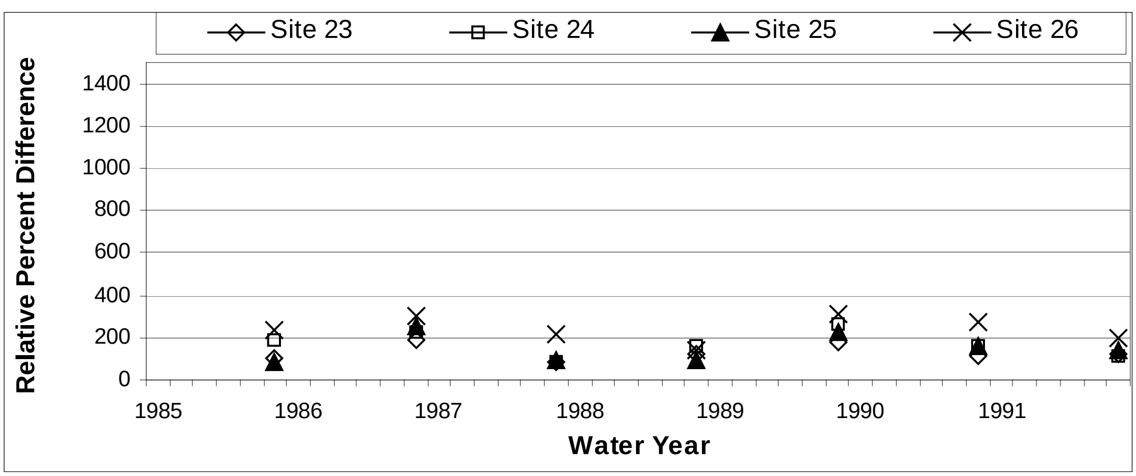


Figure VI-32. Relative percent difference between soil water SC and applied water at Gum Tree (January - June average).

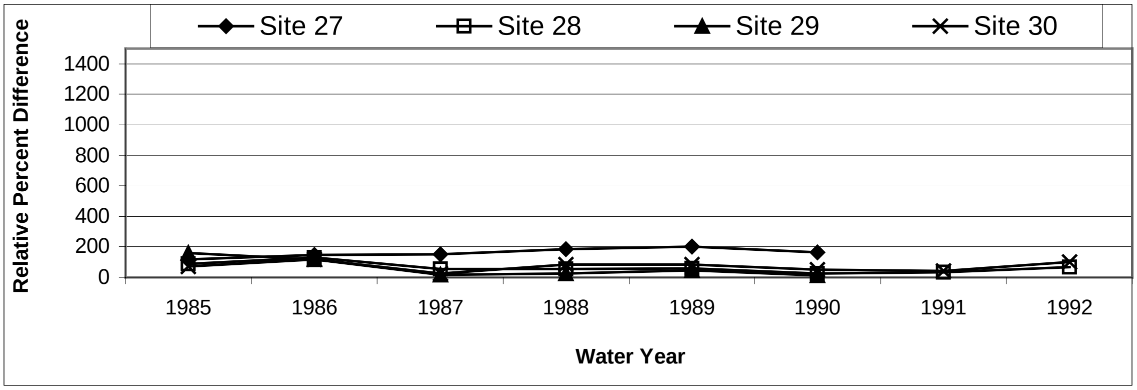


Figure VI-33. Relative percent difference between soil water SC and applied water at Grizzly King (January - June average).

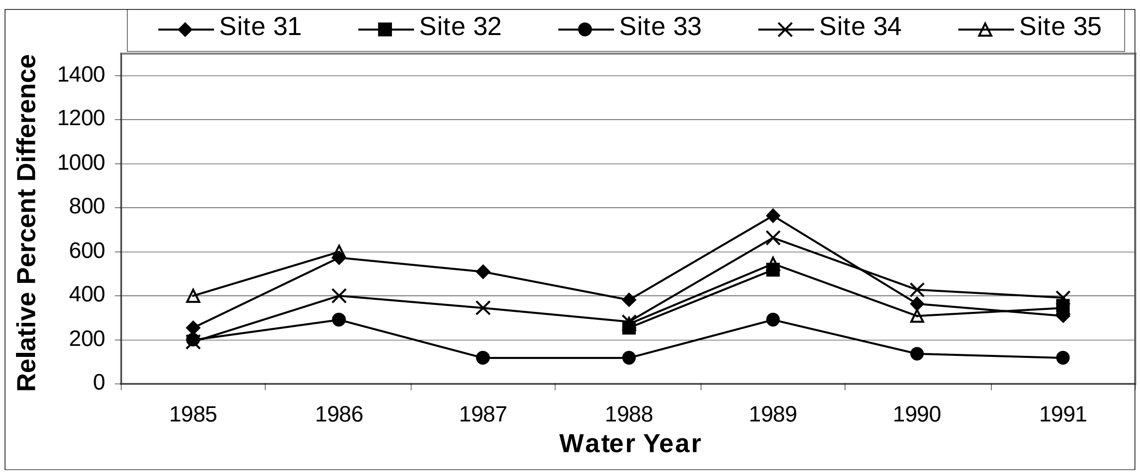


Figure VI-34. Relative percent difference between soil water SC and applied water at Sprig (January - June average).

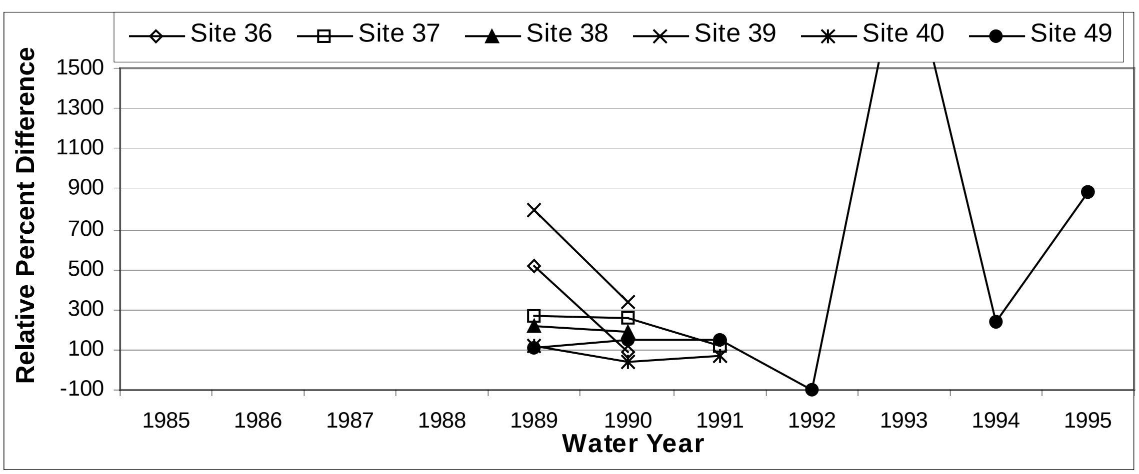


Figure VI-35. Relative percent difference between soil water SC and applied water at Grizzly Island (January - June average).

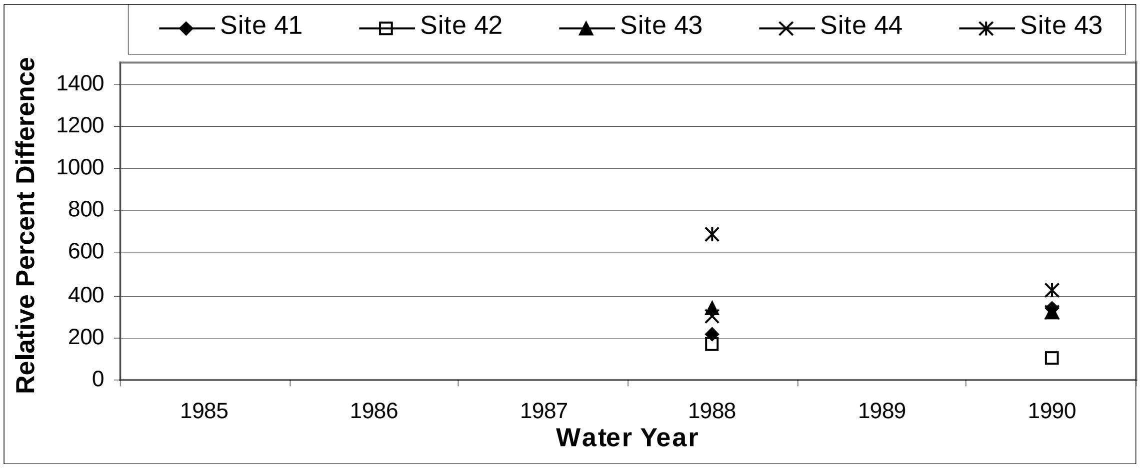


Figure VI-36. Relative percent difference between soil water SC and applied water at Mallard (January - June average).

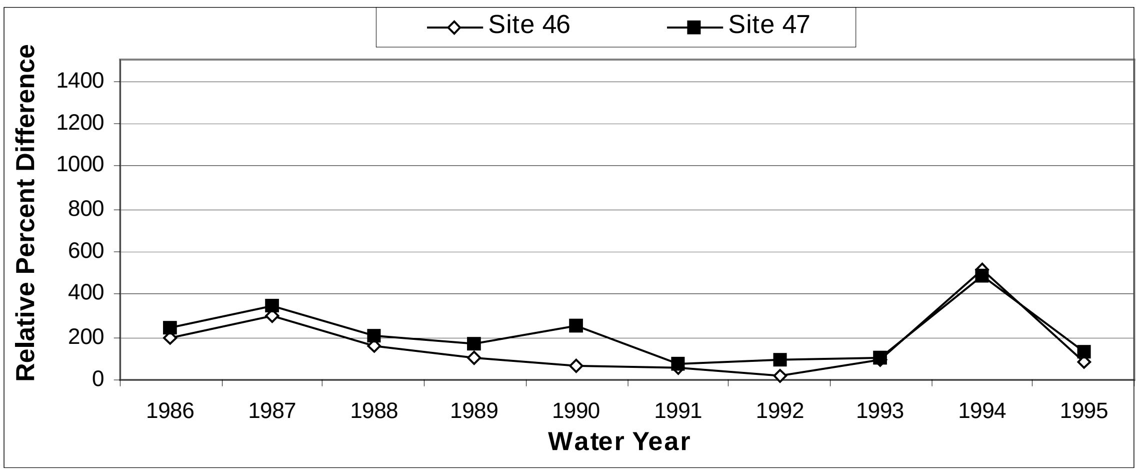


Figure VI-37. Relative percent difference between soil water SC and applied water at West Family (January - June average).

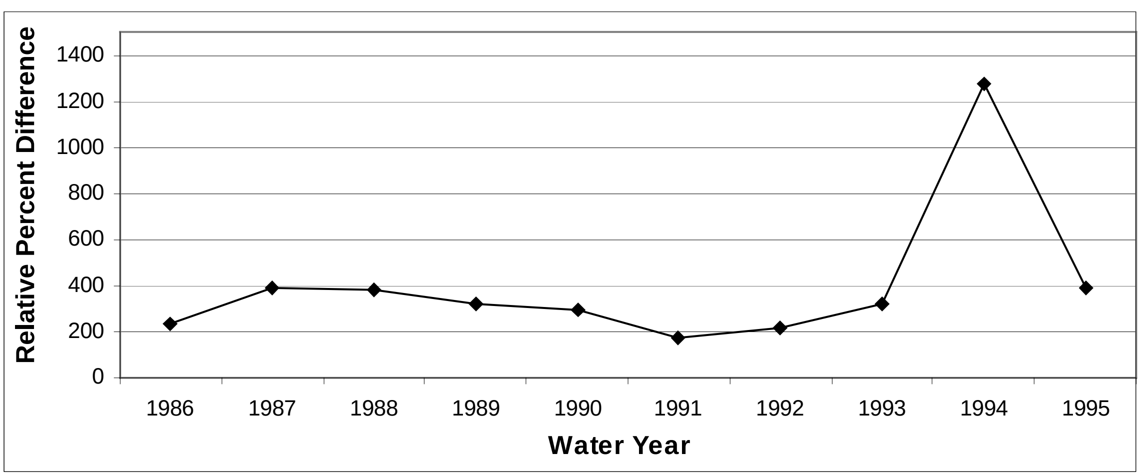


Figure VI-38. Relative percent difference between soil water SC and applied water at Goodyear (January - June average).

Spring soil water SC values at most sites was 10-20 mS/cm greater than that of the water in the adjacent channel. Many of the sites showed a trend of increasing soil water SC relative to applied water SC. While pond water SC generally tracked changes in monthly applied water SC, no such link was found for soil water SC. Although soil water SC did not appear to be affected by monthly changes in applied water SC, it did increase as applied water SC increased during the dry years 1987 to 1992. It would appear that channel water SC may ultimately drive soil water SC, but other factors, such as water management, have a more direct and immediate effect. Sites in the eastern marsh, where channel water SC is significantly lower than in the western marsh, did not show comparably lower soil water SC values.

Further analysis of the relationship between applied and soil water SC revealed a more significant relationship which is discussed in the next section.

4. Effect of October and November Applied Water Specific Conductance on Soil Water Specific Conductance

To determine if the applied water SC at the time of flood-up had a significant effect on subsequent soil water SC, four measurements were graphed for each water year at each monitored ownership: October applied water SC, November applied water SC, December – May applied water SC average, and the average soil water SC at all sites for the water year (Figures VI-39 to VI-46). The data were examined to determine if applied water SC during the initial flood up period had a more significant effect on soil water SC than average applied water SC for the remaining management period. In other words, did flooding the ponds with lower SC water in October and/or November result in lower soil water SC for the entire water year, regardless of December - May applied water SC? During the study period, most monitored ownerships flooded in October and early November. Some monitored ownerships started flooding as early as September, but there were minimal data available for evaluation. The duration of the flood-up period varied with the ability of the monitored ownership to flood quickly.

There is an observable relationship between the SC of the applied water during flood-up and the soil water SC for the water year. This is particularly apparent in cases where the October and November applied water SC had an opposite trend from the average SC for December - May. In most of these cases, soil water SC followed the same trend as the October and November SC, indicating SC of the applied water is more critical during these months than during the remainder of the management period. For example, Figure VI-39 shows the relationship between water SC at S-35 and soil water SC at Morrow Island, West Family and Goodyear. Between 1989 and 1990, October and November channel water SC decreased while average channel water SC for December - May increased. Similar to Tule Belle, soil water SC at all three clubs decreased during this time period. Between water year 1993 and 1994 a similar pattern occurred with channel water SC; however, West Family soil water SC remained about the same while Goodyear soil water SC decreased. Morrow Island soil water SC data are not available for water years 1993 and 1994.

The relationship between applied water and soil water SC at Island Club and Gum Tree Farms is shown in Figure VI-43. Between water years 1986 and 1987, 1989 and 1990, and 1993 and 1994, October/November channel water SC decreased while December - May average channel water SC increased. The effect of the October/November applied water SC was not as strong as at the other monitored ownerships. Between water years 1987 and 1988 the soil water SC at both monitored ownerships remained about the same. Between water years 1989 and 1990, the soil water SC at Island Club increased slightly, while that at Gum Tree decreased slightly. Between water years 1993 and 1994 the soil water SC at Island Club decreased significantly (data are not available for Gum Tree).

Increases in applied water SC during October and November may also result in increased soil water SC for the water year. In several cases, October and November applied water SC increased while the average applied water SC for December - May remained fairly stable or decreased. In most cases, soil water SC increased over the same time period. For example, at Teal Club (Figure VI-41), October and November applied water SC increased by 5.2 and 6.7 mS/cm, respectively, between water years 1990 and 1992, while average SC for December - May only increased by 1.1 mS/cm. During this time period soil water SC increased from 38 to 49 mS/cm. Tule Belle showed a similar pattern during water years 1988-1989 and 1990-1991. However, between water years 1992 and 1993, although applied water SC showed an increasing pattern, the soil water SC decreased slightly, following the trend of the December - May applied water SC, not the October/November applied water SC. This is likely due to the fact that the October/November applied water SC only increased by 1.6 and 1.3 mS/cm, respectively, while the average applied water SC for December - May decreased by 7.0 mS/cm.

In some cases, October and November had opposite applied water SC trends. For instance, October applied water SC increased from one year to the next, while November applied water SC decreased. In this case, it appears that soil water SC generally followed the October applied water SC pattern. This is consistent with the fact that the majority of the ponds in the marsh complete initial flood up by the end of October and circulate water in November. In Figure VI-45, which illustrates the effect of S64 applied water on Grizzly Island, October and November have opposite trends between water years 1991 and 1992. From 1991 to 1992 October applied water SC increased (10.8 to 12.9 mS/cm), while November's SC decreased (11.3 to 9.9 mS/cm). During this same time period, soil water SC increased from 16 to 26 mS/cm. Similar patterns are seen at Mallard (Figure VI-46) and Sprig (Figure VI-44) during water years 1988 and 1989. In both cases, the October applied water SC increased, while the November SC, and the December - May average SC decreased. Soil water SC at both monitored ownerships increased from water year 1988 to 1989, following the October applied water SC trend.

In cases where soil water SC follows the November applied water SC trend, pond stage records indicate that the pond flooded into November. For example, looking at Figure VI-43 for Island Club and Gum Tree, between water years 1988 and 1989, October applied water SC increased while November applied water SC decreased. Gum Tree soil water SC increased 4 mS/cm 9from 31 to 35 mS/cm), following the same pattern as the October applied water SC. However, Island Club soil water SC followed the November applied water SC pattern, and decreased 8 mS/cm (from 29 to 21 mS/cm). Pond stage recorder data indicate that Island Club continued flooding through November, likely influencing the soil water SC. A similar pattern was seen at Sprig between water years 1986 and 1987.

Based on the available data, there is evidence supporting the theory that October/November applied water SC significantly affects soil water SC for the entire water year. With the available data, 48 complete year to year comparisons can be made.

- Of the 48 comparisons, soil water SC changes followed October and/or November applied water SC changes 38 times, or 79 percent.
- In some cases where soil water SC did not follow October/November applied water SC, the October/November SC change is small compared to the change in the December - May average.
- In 23 cases (48 percent) October and/or November applied water SC followed an opposite trend as the December - May average applied water SC. In 17 of the 23 cases (74 percent), soil water SC followed the same trend as the October and/or November SC.
- When October and/or November had an opposite SC trend as December - May (about 50 percent), soil water SC followed the October and/or November applied water SC trend the majority of the time.
- Of the 48 data points, 35 percent had soil water SC corresponding with the October/November applied water SC when the October/November applied water SC trend was opposite that of the December - May applied water SC.

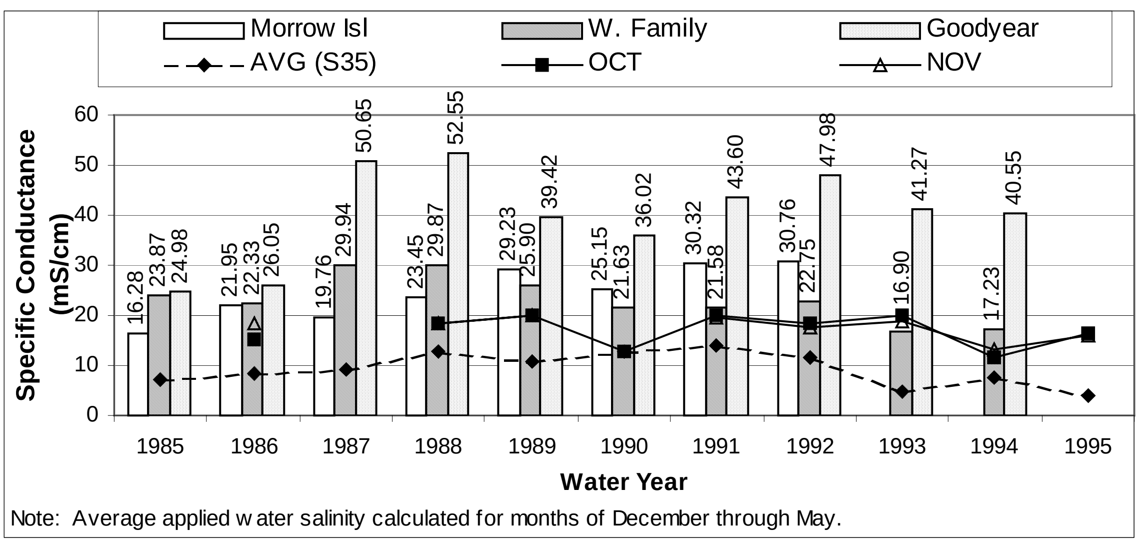


Figure VI-39. Comparison of applied water SC from S-35 and soil water SC at Morrow Island, West Family, and Goodyear.

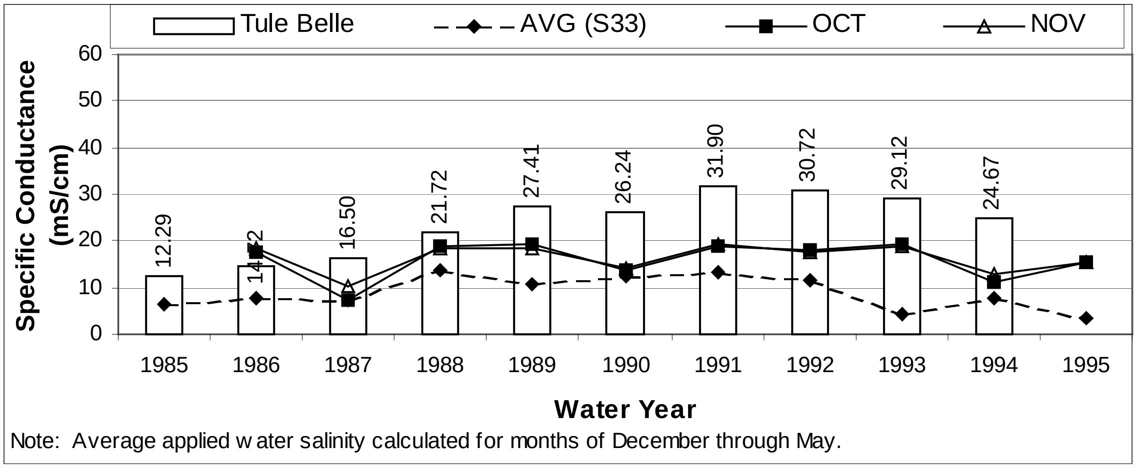


Figure VI-40. Comparison of applied water SC from S-33 and soil water SC at Tule Belle.

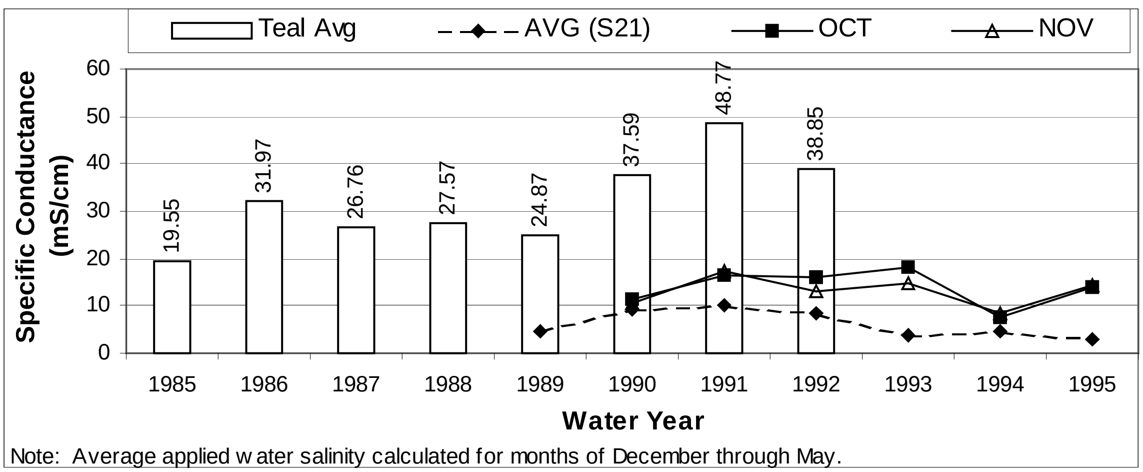


Figure VI-41. Comparison of applied water SC from S-21 and soil water SC at Teal Club.

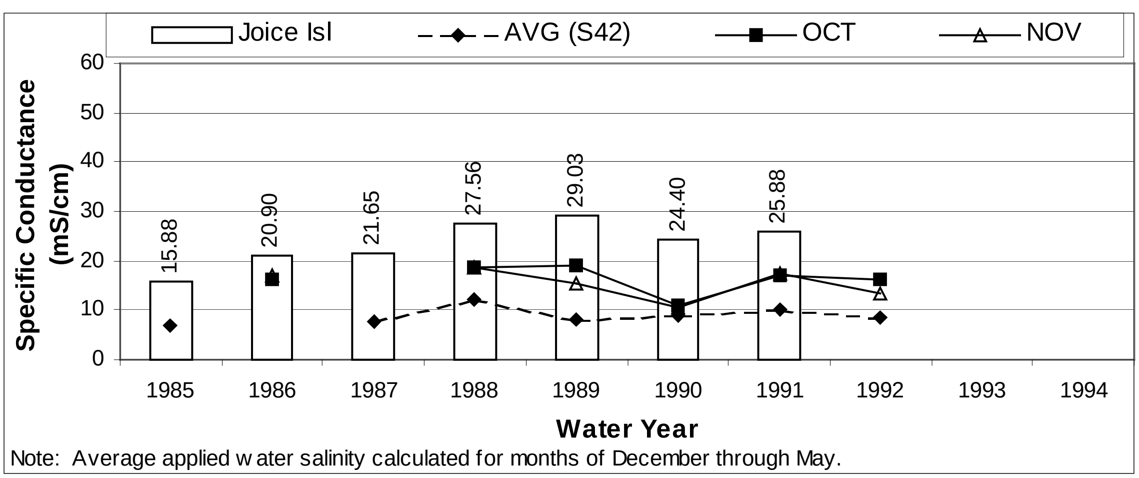


Figure VI-42. Comparison of applied water SC from S-42 and soil water SC at Joice Island.

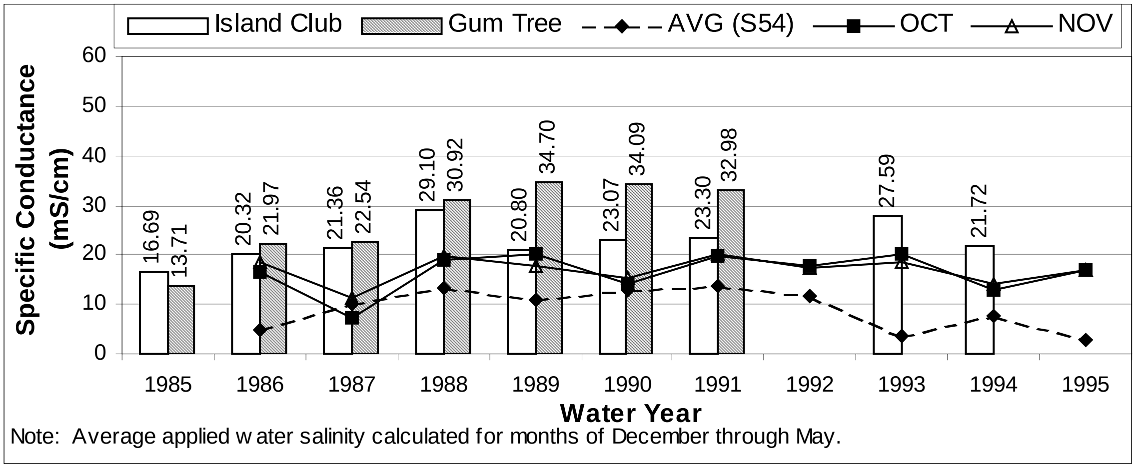


Figure VI-43. Comparison of applied water SC from S-54 and soil water SC at Island Club and Gum Tree.

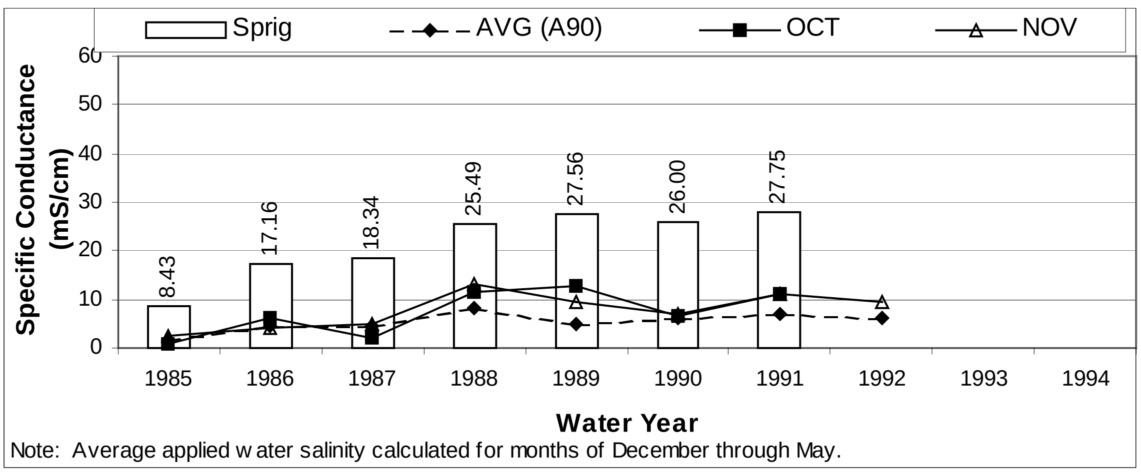


Figure VI-44. Comparison of applied water SC from A-90 and soil water SC at Sprig.

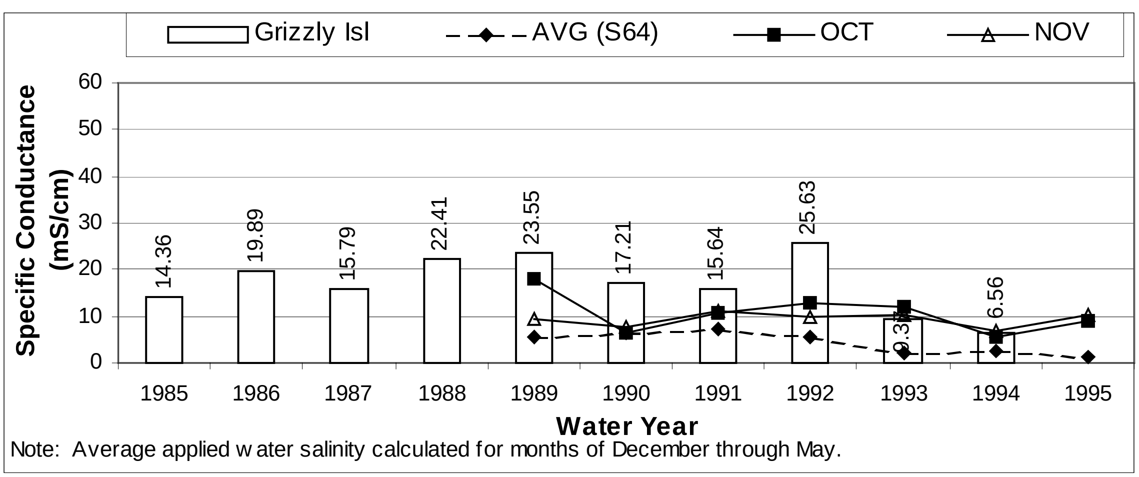


Figure VI-45. Comparison of applied water SC from S-64 on soil water SC at Grizzly Island.

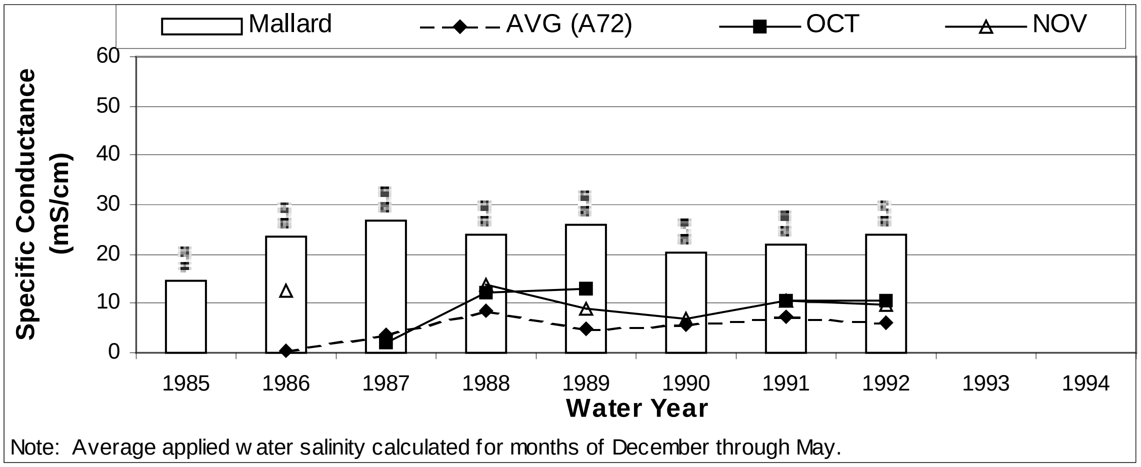


Figure VI-46. Comparison of applied water SC from A-72 and soil water SC at Mallard.

5. Within-ownership Variation in Soil Water Specific Conductance

The soil water SC measured on the monitored ownerships showed great within-ownership variability (figures VI-1 to VI-12). Large differences in soil water SC recorded within the individual ownerships are due to different ambient conditions at the soil tube sites such as variations in soil type, pond bottom elevation (or topography), distance to intake and drain structures, and distance to water conveyance facilities such as primary, secondary, and V-ditches.

Although edaphic and hydrologic characteristics of the soil tube sites varied greatly even on the same ownership, it appears that a significant factor influencing the SC of soil water is the location of the monitoring site relative to water flow; most importantly, a water intake structure, and secondarily, a ditch. The location of the soil SC monitoring sites in relation to intake and drain structures was compared with soil water SC to determine if a relationship exists.

Only Morrow Island (Figure VI-1) and West Family (Figure VI-11) had fairly uniform soil water SC values across the soil tube sites. Morrow Island has several water control structures for diversion, allowing for fairly uniform flooding of the ponds. West Family has one diversion structure; however, the pond is fairly small, allowing for uniform flooding.

The remaining monitored ownerships had significant variability among soil water SC at one or more sites. Island Club and Mallard had the highest soil water SC at the sites located farthest from the intake structure(s). Island Club is managed as one large pond with the intake structure located along the northwest portion. Sites 21 and 22, which were in the southern portion of the pond, furthest from the intake, generally had the highest soil water SC. Mallard has two intakes on the northern edge of the pond, one on the west end and one on the east. The two sites with the highest SC values were located in the southern portion of the pond, a considerable distance from the intakes.

The monitored area of Grizzly Island is comprised of eight ponds with a complex system of interconnecting ditches. Water is diverted from Montezuma Slough and circulated across the ponds. As can be expected from this complex system, the soil water SC values were fairly variable from site to site. However, site 40 consistently had the lowest soil water SC. This site was the closest to the water intake structure and was also located next to a ditch. Site 39 (in the same pond as site 40) recorded the highest soil SC in five of the six years it was monitored possibly because this site received little flow of low SC water diverted from the slough.

Joice Island consists of four separate ponds with intake and drainage structures on the surrounding sloughs. Generally site 17, located the furthest from an intake structure, had the highest soil water SC values. Site 15 generally had the lowest soil water SC. This site is located next to a drain, and is fairly distant from an intake. Site 16, which had fairly low soil water SC until water years 1990 and 1991 is located closer to the intake than the drain. Site 18 was the closest to an intake structure, and generally had low soil water SC with respect to the other sites.

Like Grizzly and Joice islands, Teal is composed of several cells. The club is divided into two ponds, an east pond composed of one cell, and a west pond composed of three cells. Sites 12 and 14 generally had significantly higher soil water SC than the other sites. Site 12 is located in the west pond’s cell 3, furthest from the intake structure in cell 2. Cell 3 only receives water after it is circulated through cells 2 and 4. Site 14 is along the eastern edge of the east pond, which diverts water directly from Frank Horan Slough. Therefore, distance from the intake structure does not explain the high SC at this site. Site 11 consistently recorded the lowest soil SC of the four soil tube sites on this ownership. This site was located on a hydrologically separate, 44-acre portion that had both intake and drain structures that allowed for quick flood/drain capability. The monitoring site was in the path of water flow across the pond, allowing for quicker, more frequent exchange of water between the slough and pond.

The soil water SC recorded by the five sites on Sprig Farm showed great variation both between sites and between years, but site 33 consistently had the lowest soil water SC values. Sites 33 and 31 are located about the same distance from the intake structure, but site 33 was often half as saline as site 31. Site 33 was situated along a primary ditch and received good flow from the Roaring River intake while site 31 appeared to be isolated between two intake structures and to receive very little flow.

The two sites on Sunrise Club documented large differences in soil SC even though the sites were less than 100 yards apart. The SC measured at site 50 was one-half to one-quarter that of the soil SC measured at site 51 and both sites were approximately the same distance from the water intake structures. Site 50 was located closer to a ditch, in this case, a secondary ditch, where water flowed past on the way from the intake structure to the drain gates near the clubhouse. Ponding of water around site 51 indicates that it is at a lower elevation than site 50, and this ponding and subsequent evaporation of water and deposition of salts is probably responsible for the higher soil water SC at this site.

Gum Tree and Grizzly King had the highest soil water SC values at sites located next to the intake structures. Grizzly King flooded with Grizzly Bay water during the entire study period. Gum Tree flooded with Grizzly Bay water until 1988. These data indicate that extended exposure to Grizzly Bay water may increase soil water SC.

The above evaluation suggests a correlation between site location and soil water SC. Data analysis indicates that soil SC may be influenced by the proximity of the monitoring sites to the source of applied water and the path of water flow across the pond. In many cases, the closer a site was to the water intake source the less saline the soil was. This was probably due to two factors: (1) the soil was saturated with lower salinity water, because the water reached the site before it picked up additional solutes from the soil; and/or (2) the greatest flow or “circulation” effects occurred in areas closest to the intake structure. Circulation would also increase with proximity to flow paths such as ditches. Therefore, soils are inundated more often with greater volumes of lower salinity water the closer they are to the water delivery system. The exception occurred at Gum Tree and Grizzly King, which were flooded with Grizzly Bay water during part or all of the study period. At these sites, the opposite pattern was observed.

Other environmental factors such as pond bottom elevation likely play a significant role in the SC of soils in the Suisun Marsh. Water flow rates are likely influenced by pond bottom elevation or topography where soils that are slightly elevated drain more easily than soils that have subsided and collect water. It remains unclear whether the mechanism responsible for changing soil SC is (1) the volume of the water that may decrease the concentration of solutes in the soil or (2) the rate of water flow through the soil pores and transportation of salts through the soil profile (vertically or horizontally) or (3) a combination of the two.

6. Effect of Soil Type on Soil Water Specific Conductance

Soil types in the Suisun Marsh have varying permeability based on the relative amounts of clay and organic components. Water has higher flow rates through soil types with higher proportions of organic matter than soils with higher proportions of clay, and in standardized tests the soil structure was found to influence soil water SC (Miller et al 1975). However, the data collected by the monitoring program do not show this effect, possibly because other factors complicate the relationship between soil type and soil water SC. Table VI-2 summarizes the soil characteristics and qualities as reported in Miller et al 1975.

Soil type was compared with soil water SC to see if a relationship exists between the two. As discussed in Chapter 1, five soil series are commonly found in the marsh: Joice, Reyes, Suisun, Tamba, and Valdez. The Suisun, Joice, Tamba and Reyes soils are associated with the Delta landforms. They are mixtures of hydrophytic plant remains and mineral sediments. The soils range from organic types containing small amounts of mineral matter to mineral soils with little organic matter. The four soil types generally occur in the following order extending outward from the sloughs: Reyes, Tamba, Joice, and Suisun. Soils with higher mineral content are generally located adjacent to the sloughs, where most of the mineral sediments are deposited in vegetation when high tides and floodwater spread outward from the sloughs. Farther from the sloughs, where soils are at lower elevation and drainage is poorer, less sediment has been deposited. The result has been a greater ratio of organic matter to mineral matter. The Valdez series soils are composed of alluvium deposited as natural levees and flood plain sediment. The sediments are mineralogically heterogeneous as they originated from a variety of very recent deposits. The marsh soils are generally acidic, with high SC and low fertility.

Figure VI-47 shows the distribution of soil types on the monitored ownerships. As can be seen in the figure, the soil types are grouped by geographical location (also see soils map in Miller et al 1975). The Reyes and Joice soils are the most prevalent soil types in the monitoring program, and were found primarily in the monitored ownerships in the western marsh. Thirteen sites on nine monitored ownerships were located in Reyes silty clay. Sixteen sites on nine monitored ownerships were located in Joice muck. The Valdez and Suisun soils are more common in the eastern marsh. The Valdez soils were found on seven sites at four monitored ownerships. Suisun peaty muck was found at three sites on three monitored ownerships. The Tamba soils are distributed fairly evenly across the marsh, although they cover a larger portion of the monitored ownerships in the western marsh than the eastern marsh. Tamba soils were found at nine sites on seven monitored ownerships.

Annual average soil water SC and soil type evaluated to determine if there was any relationship between soil type and soil water SC. Because all the soil types in the marsh are poorly drained, acidic, and have high salinity, no apparent relationship would be expected. Generally, evaluation of the data did not show a strong relationship between soil type and soil water SC. Joice Island, Morrow Island, Goodyear, and West Family each had the same soil type at all monitoring sites. Joice Island had significant variability among soil SC at its sites, while West Family and Morrow had little variability. Grizzly King and Gum Tree each had two soil types at the monitored sites. Three of the sites at Grizzly King were located on Valdez silty clay loam, while one site was located on unclassified tidal marsh soil. This site generally had the lowest SC; however, this is likely due to location of the site, in the muted tidal area outside of the ponded area, rather than soil type. Three of the sites at Gum Tree were located in Joice muck, and one was located in Reyes silty clay. It is interesting to note that the Reyes silty clay site consistently had the highest SC; however, it is most likely due to site location relative to infrastructure rather than soil type. The variation in soil water SC among sites in the same pond is more thoroughly discussed in Section 4 above, *Within-ownership Variation in Soil Water SC*.

The remaining monitored ownerships all had three or more soil types at the monitored sites. No consistent patterns of soil water SC were seen based on soil type. Significant variability in soil water SC was seen among sites with the same soil type, while sites with different soil types had similar soil water SC. For example, the sites with the highest and lowest SC at Tule Belle and Teal had the same soil type. At Sprig, all of the five sites were on different soil types; however, soil water SC throughout the pond was fairly homogenous. Based on this evaluation, it is likely that other factors such as site location,

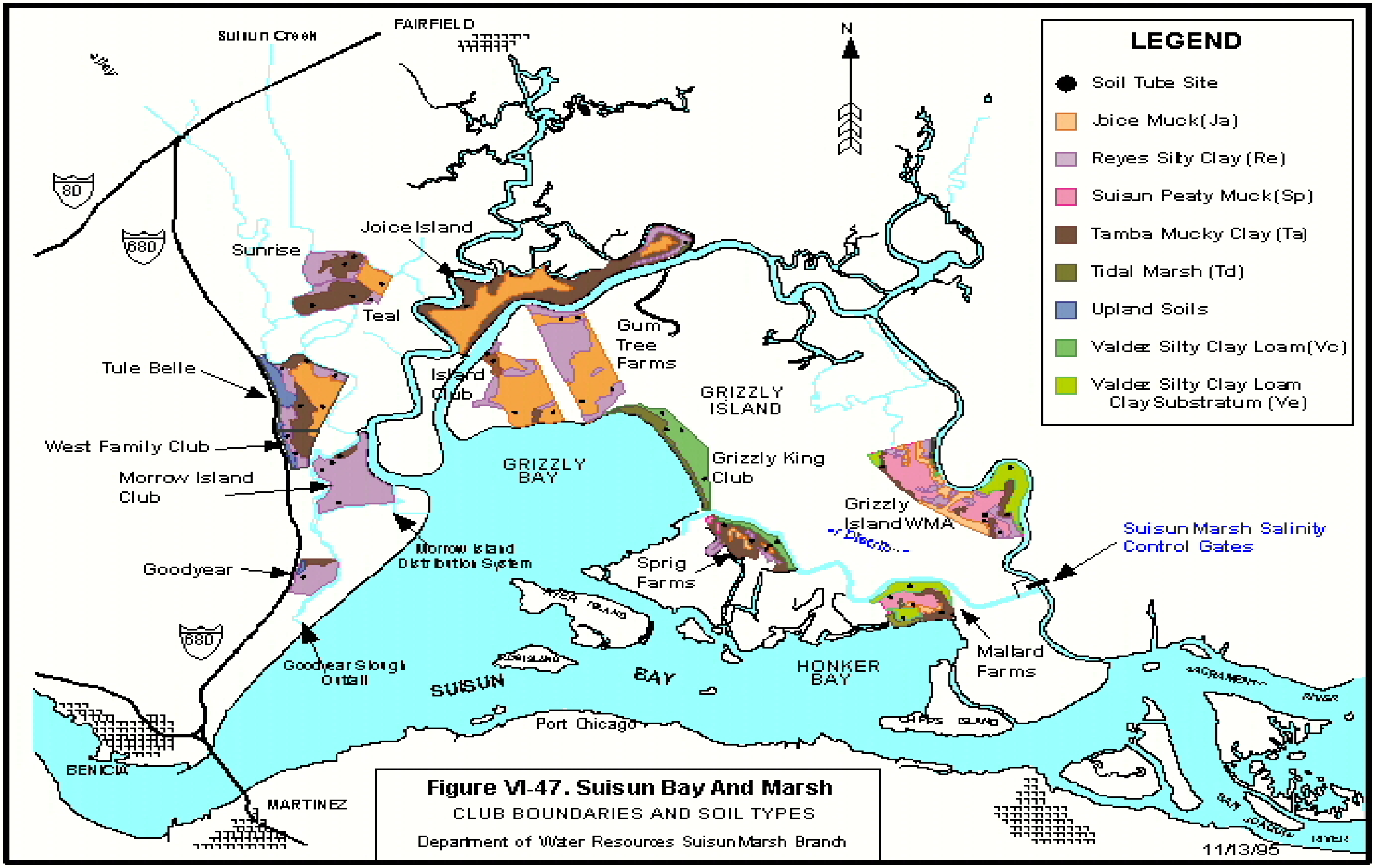


Figure VI-47. Suisun Bay And Marsh
CLUB BOUNDARIES AND SOIL TYPES
Department of Water Resources Suisun Marsh Branch

site elevation, and water management exert a more significant impact on soil water SC than soil type.

Table VI-2. Suisun Marsh soil characteristics and qualities.

Soil Series[1]	Soil Type	Salinity[2]	Drainage
Valdez	Valdez silty clay loam	Moderate	Somewhat poorly drained
Reyes	Reyes silty clay	Very high	Poorly drained
Tamba	Tamba mucky clay	Very high	Very poorly drained
Joice	Joice clayey muck	Very high	Very poorly drained
Suisun	Suisun peaty muck	Very high	Very poorly drained

Table adapted from Miller et al, 1975.

1/ Soil series listed in order of increasing organic matter content.

2/ Salinity of the soil is based on the electrical conductivity of the saturated soil extract, as expressed in mmhos/cm. Salinity is rated as none (less than 2.0), low (2.0-4.0), moderate (4.0-8.0), high (8.0-16.0), and very high (more than 16.0).

7. Soil Water Specific Conductance at Depths of 18 and 30 Inches

The management plans for most of the monitored ownerships recommended following the late drawdown management regime which favors the growth of alkali bulrush. However, three of the monitored ownerships, West Family (sites 46 and 47), Goodyear (Site 48), and Grizzly Island Pond 7 (Site 49) had management plans calling for the early drawdown water management regime, which favors the growth of fat hen. Fat hen's roots extend further into the soil than those of alkali bulrush, so in addition to the 6-inch-deep soil water extractors common to all the sites, these four sites also had soil water extractors at 18- and 30-inch depths.

Monthly values for soil water SC at each site for all three depths are graphed in Figures VI-48 to VI-51. At West Family and Goodyear, soil water SC at 18 and 30 inches appeared to be more stable from month to month than at 6 inches (Figures VI-48 to VI-50). This was tested using a Tukey-type multiple comparison for differences among variances which proposes three null hypotheses: variance at 6 inches=variance at 18 inches, variance at 6 inches=30 inches, and variance at 18 inches=30 inches (Zar 1999). The assumption that soil water SC at 6 inches is more variable than that at 18 inches or 30 inches was borne out at West Family Site 47 and Goodyear Site 48 (reject null hypotheses 6"=18" and 6"=30" and accept 18"=30"), but was not found to be the case at West Family Site 46 and Grizzly Island Site 49. At West Family Site 46 the variability at all three depths were dissimilar (reject all three null hypotheses), and at Grizzly Island Site 49 soil water SC at all depths were equally variable (accept all three null hypotheses).

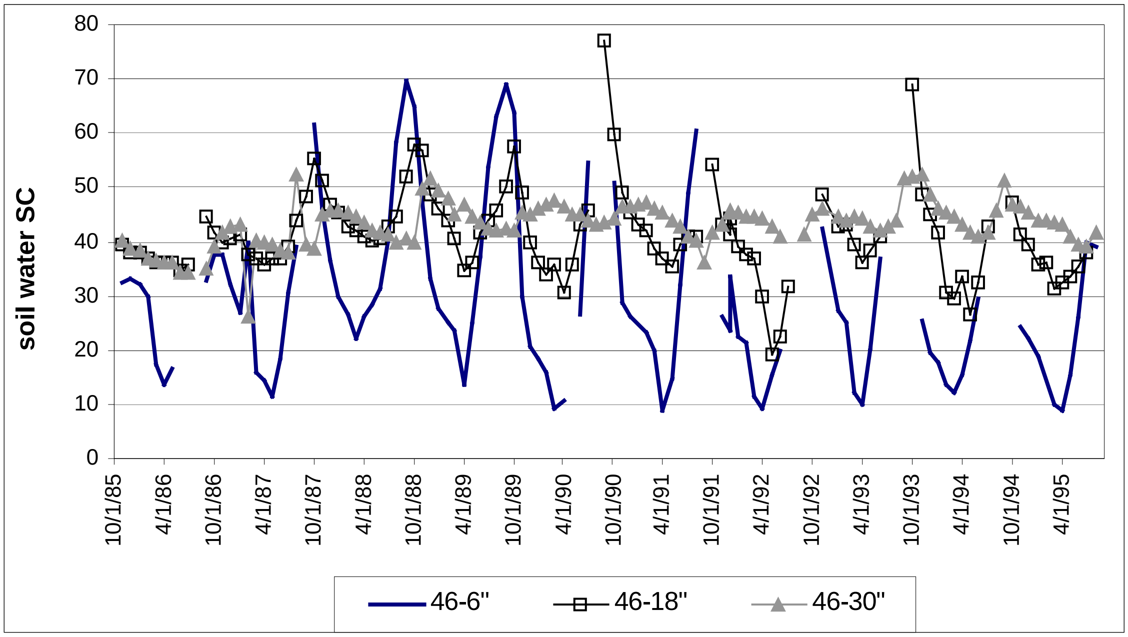


Figure VI-48. Monthly soil water SC values at three depths, West Family Site 46 WY86-95.

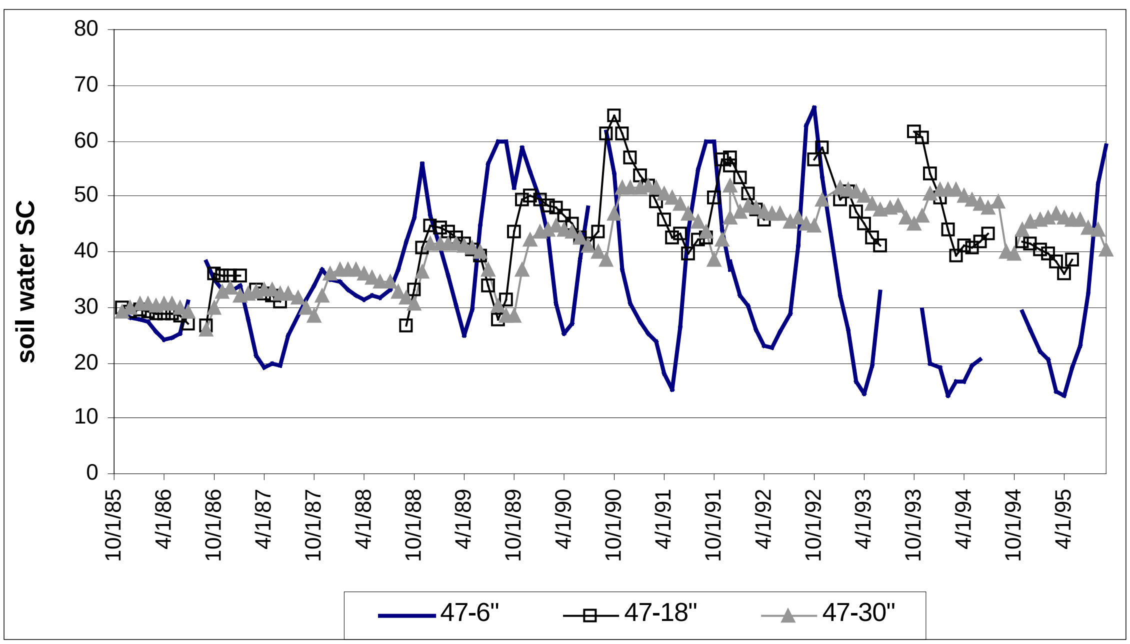


Figure VI-49. Monthly soil water SC values at three depths, West Family Site 47 WY86-95.

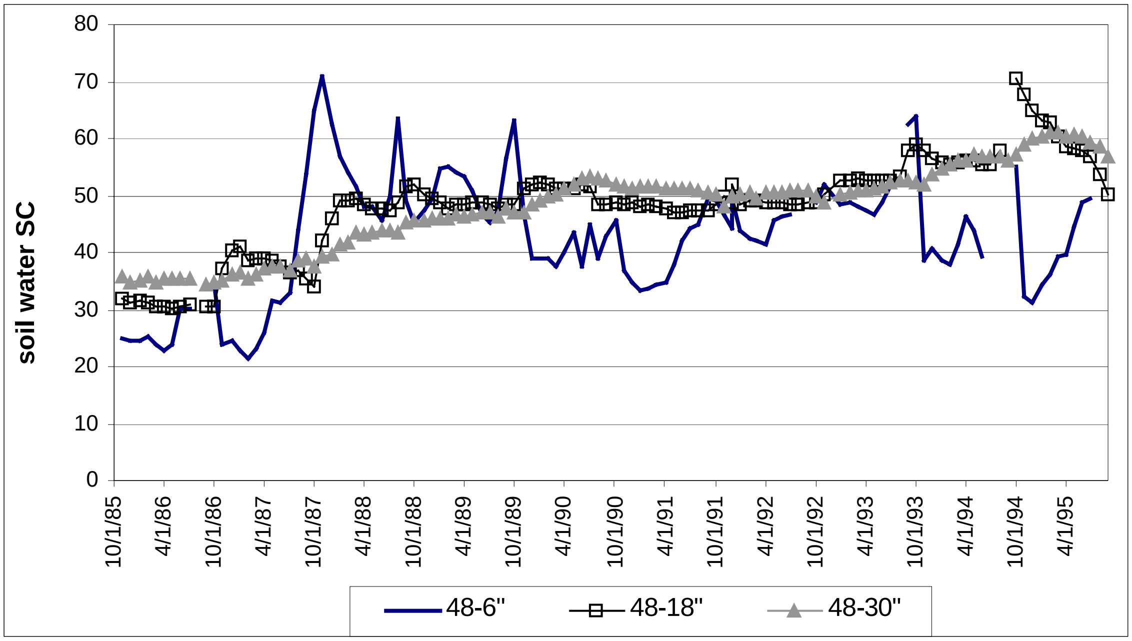


Figure VI-50. Monthly soil water SC values at three depths, Goodyear Site 48 WY86-95.

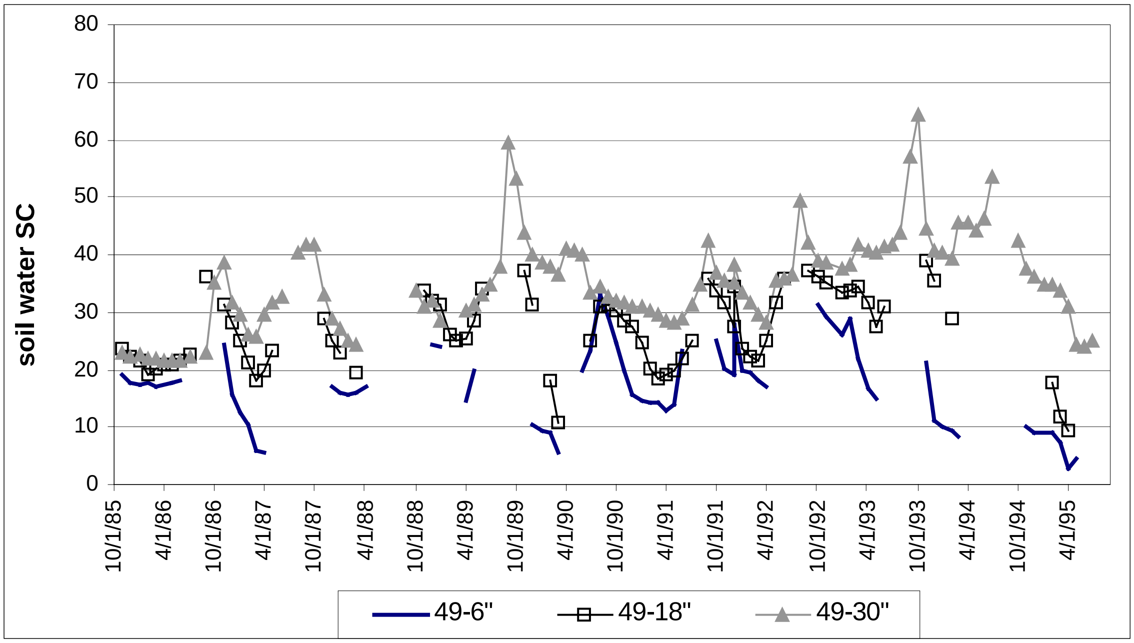


Figure VI-51. Monthly soil water SC values at three depths, Grizzly Island Site 49 WY86-95.

To compare values of soil water SC at the three depths, January-June averages for each site are graphed in Figures VI-52 to VI-55. These bar graphs include error bars denoting +/- one standard deviation. In all years at West Family Site 46, annual average soil water SC was significantly lower at 6 inches than at 18 or 30 inches. During most years, annual average SC at 30 inches was higher than at 18”, but this was significant only half the time. Soil water SC at West Family Site 47 did not follow the same trends as Site 46. Annual average soil water SC at 6” was markedly lower only from 1991 to 1995, and during most years there was no significant difference between averages at 18 and 30 inches. At Goodyear Site 48, annual average soil water SC at 6” tended to be much higher than at the other three sites, and numerically closer to the values at 18 and 30 inches. During most years, annual averages at 18 and 30 inches were numerically close, but statistically different. At Grizzly Island Site 49, annual average soil water SC values always increased with depth, although in three years there was no significant difference between values at 18 and 30 inches, and in two years there was no significant difference between values at 6 and 18 inches.

At the three monitored ownerships, there did not appear to be a consistent relationship between soil water SC at the three depths. At West Family, where water was closely managed and leach cycles were regularly conducted, SC at each level fluctuated greatly from month to month, especially at the 6 inch depth. Because all three levels tended to increase and decrease at about the same time, it did not appear that the lower levels were acting as a “salt reservoir”. If that had been the case, when SC rose at the 6 inch depth, it would have decreased at the lower depths. At Goodyear, the effects of water management are seen at all three depths. During 1986 and 1987, when the early drawdown management regime was followed, soil water SC at all three depths was fairly low and stable. During a property transfer in 1988, there was no water management and SC at all levels increased. Afterwards, when the property was flooded only for duck season and no leaching was done, SC continued to rise, especially at the lower levels. Grizzly Island is located in the eastern marsh, where channel water SC is lower than in the western marsh where West Family and Goodyear are located. The soil water SC at Grizzly Island looks quite different than that at the other two ownerships. Soil water SC at 18 and 30 inches fluctuated from month to month much more at Grizzly Island. It was also apparent here that the lower levels did not act as salt reservoirs.

8. Soil Water pH

Soil water pH was only recorded from water year 1985 through water year 1987, and the discussion of the data is included in the pond water chapter (Chapter 4).

C. Conclusions

The soil water SC increased at many of the monitored sites during the 1987-1992 drought. Other sites showed fluctuations from year to year, but maximum values almost always increased during the drought period. Most of the sites monitored from 1993 to 1995 decreased in soil water SC. Soil water SC values did not appear to be directly tied to monthly channel water SC values, but the SC of channel water during flood up of the ponds did often directly influence the soil water SC throughout the year. Substantial decreases in channel water SC (as in 1993) were usually not detected in soil water SC until the following year, and were of lesser magnitude. Because channel water SC did not show a strong short-term correlation to soil water SC, there was no clear-cut relationship between the location of a site in the marsh and soil water SC.

All monitored ownerships (except Goodyear) had multiple sites, and there was substantial variation of soil water SC among sites. One factor responsible for these within ownership variations was proximity to water control structures. At most monitored ownerships, the site(s) closest to intake structures or circulation ditches had the lowest soil water SC. Soil type did not appear to have predictable effects on soil water SC.

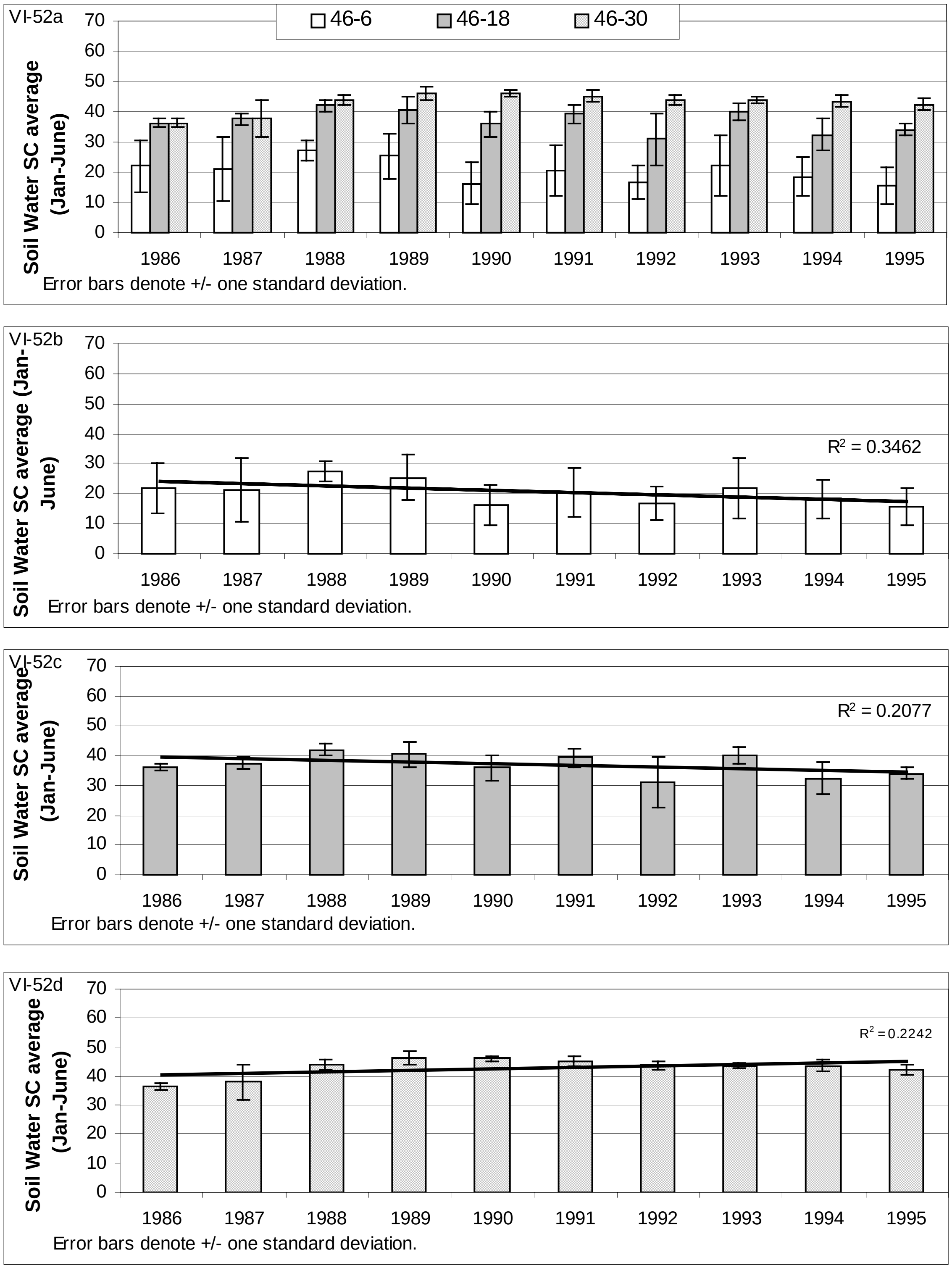


Figure VI-52. Soil water SC average at West Family Site 46, WY86-95.
VI-52a. Soil water SC average at three depths.
VI-52b. Soil water SC average at 6” depth with trend line.
VI-52c. Soil water SC average at 18” depth with trend line.
VI-52d. Soil water SC average at 30” depth with trend line.

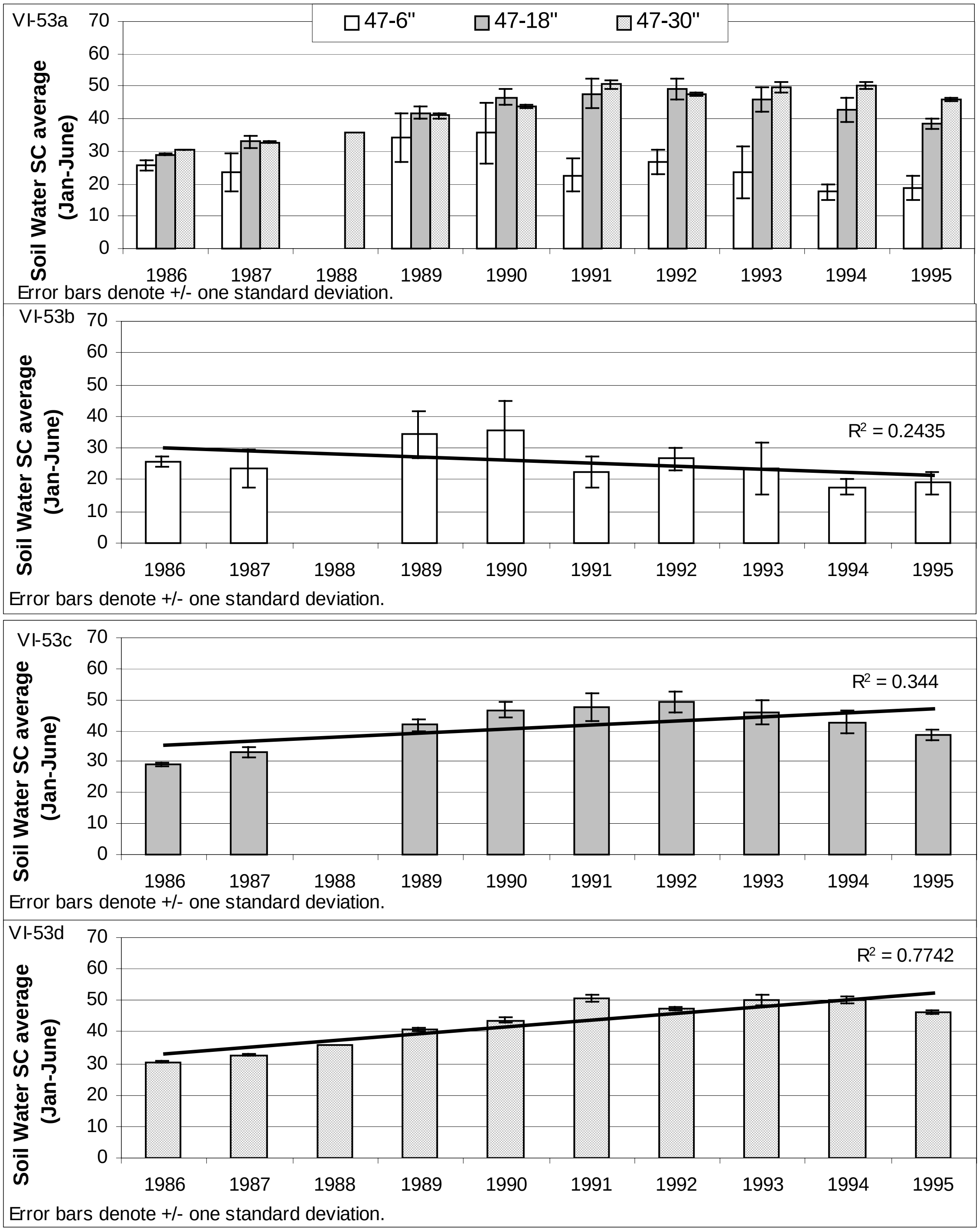


Figure VI-53. Soil water SC average at West Family Site 47, WY86-95.
VI-53a. Soil water SC average at three depths.
VI-53b. Soil water SC average at 6" depth with trend line.
IV-53c. Soil water SC average at 18" depth with trend line.
IV-53d. Soil water SC average at 30" depth with trend line.

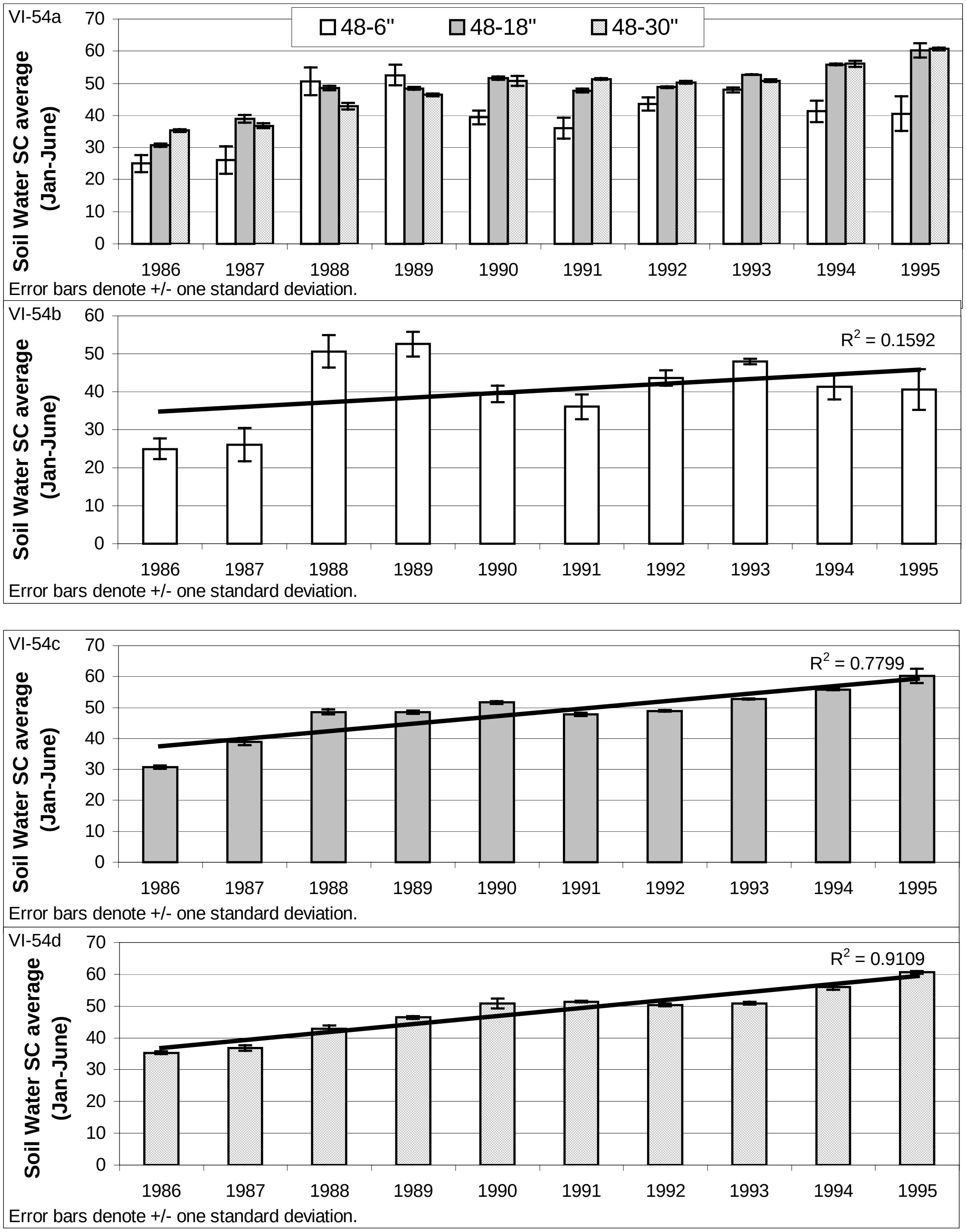


Figure VI-54. Soil water SC average at Goodyear Site 48, WY86-95.
VI-54a. Soil water SC average at three depths.
VI-54b. Soil water SC average at 6" depth with trend line.
VI-54c. Soil water SC average at 18" depth with trend line.
VI-54d. Soil water SC average at 30" depth with trend line.

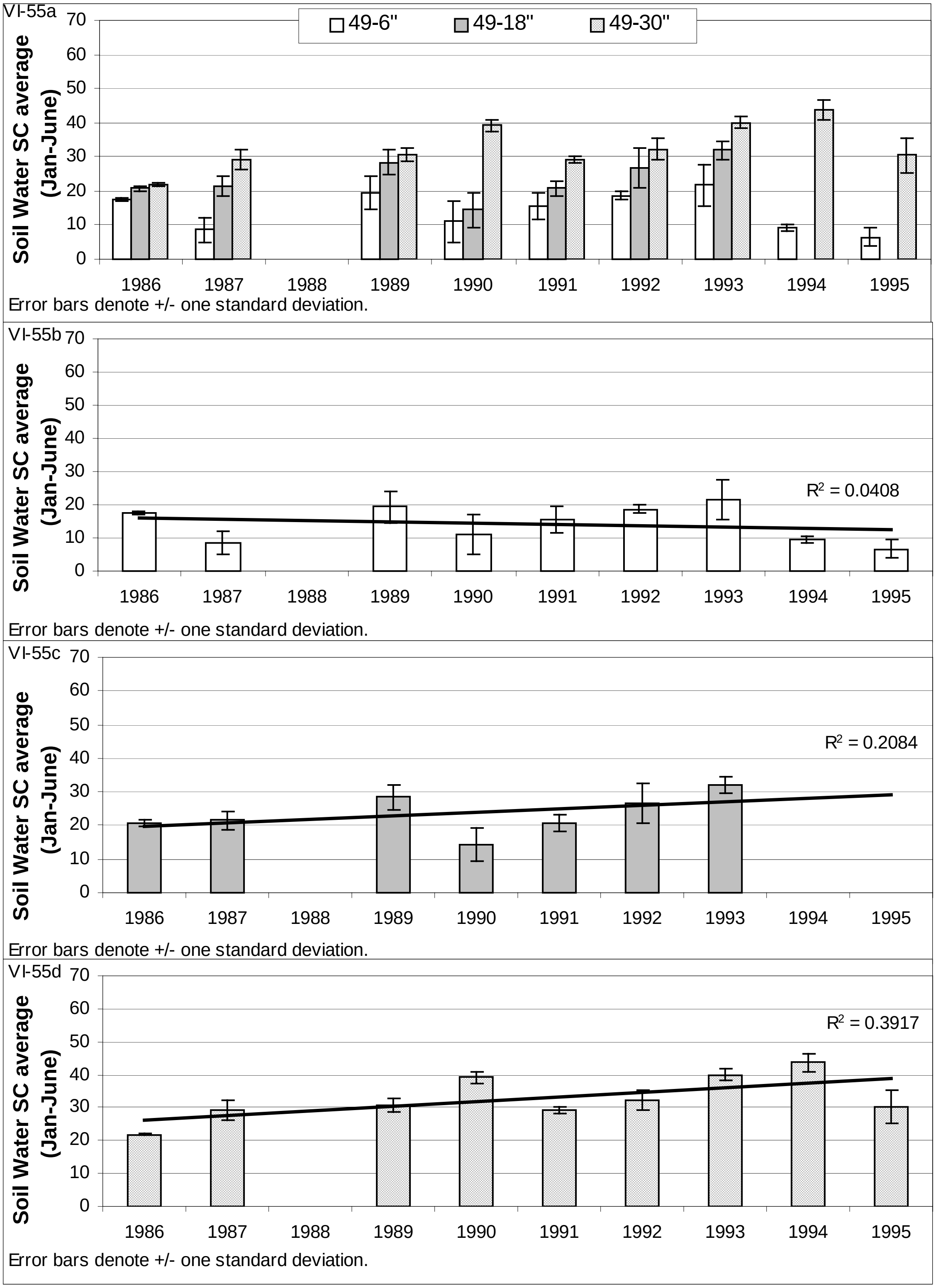


Figure VI-55. Soil water SC average at Grizzly Island Site 49, WY86-95.
VI-55a. Soil water SC average at three depths.
VI-55b. Soil water SC average at 6" depth with trend line.
VI-55c. Soil water SC average at 18" depth with trend line.
IV-55d. Soil water SC average at 30" depth with trend line.

D. Recommendations

It is apparent from the monitoring program that many factors contribute to the soil water SC at any given site in Suisun Marsh. Future monitoring of soil water SC should include more intensive monitoring of individual sites, including more collection sites within a single pond, more frequent data collection, and measurements of soil moisture.

Soil water SC seems to respond quickly to some effects, like leaching (see Chapter XI, Management), and more slowly to other factors, like applied water SC. To more accurately track such changes, two things are necessary: collect data more often than monthly, and design experiments so that it is possible to control affecting factors. When SC data are only collected on a monthly basis, the effects of short-term events like precipitation and management actions cannot be accurately assessed. To measure the effects of factors such as channel water SC, which can take several months or a year to significantly affect soil water SC, other factors must be controlled so that measured changes can be attributed to a single factor. Ideally, study sites would be selected for features that would allow for controlled tests to measure the independent effects of different factors such as SC of applied water, hydroperiod, leaching, soil type, and distance from water control facilities.

It would also be advantageous to measure the soil water SC within the tidal wetlands. It is known that the 1987-1992 drought caused increases in soil water SC within the managed wetlands, but it is not known whether there were significant increases in the tidal wetlands. Although measurements have been made elsewhere in tidal wetlands, there are no known data on soil water SC in the undiked areas of Suisun Marsh. If studies found that the tidal wetlands are more resistant to long-term increases in channel water SC, this could suggest management strategies (such as maintaining higher levels of soil moisture) that could minimize soil water SC increases in the diked wetlands.

Because soil water SC is dependent upon the amount of water in the soil, it is also important to measure the soil moisture when measuring soil water SC. With this additional information, the salt amount is known along with the salt concentration.

Because soil salinity is highly spatially it is recommended that future monitoring either greatly increase the number of solution extractors in a localized area or utilize an instrument the can measure SC with a larger volume of measurement, such as electromagnetic induction (EM). There are limitation to each of these methods alone, so the use of both in combination would provide improved understanding of the system. A large number of localized solution samplers could be used to establish the local spatial structure of salinity and to monitor the spatio-temporal change within that local structure. The EM could be used to monitor larger scale spatio-temporal changes.

In addition, EM should be used as an initial survey tool to decide where to place extractors over the entire study area. Using specially developed software, the location of sample sites can be selected in locations to reflect the spatial variability of the existing soil salinity. The selection of the sample locations as done in the past monitoring program have no statistical justification. This immediately draws into question conclusions drawn concerning spatio-temporal change in salinity. Conclusions such as "there was no clear-cut relationship between the location of a site in the marsh and soil water SC" might only be due to poor sample design.

Notes:

Corwin, D. (USDA Salinity Lab). 17 April 2000. Email addressed to P. Finfrock, Department of Water Resources, Environmental Services Office.

Chapter VII
Vegetation Monitoring

The Monitoring Agreement required three types of vegetation monitoring:

- **Vegetation occurrence.** Vegetation around each soil water monitoring site to be surveyed during August or September each year.
- **Vegetation production.** At the late drawdown ownerships (soil water tubes at 6 inch depth only), alkali bulrush seeds were to be collected each fall to estimate production, while at the early drawdown ownerships (soil water tubes at 6, 18, and 30 inch depths), fat hen plants were to be collected to estimate biomass.
- **Marsh-wide vegetation survey.** Overall vegetative composition of the marsh was to be determined by aerial photography and ground verification every three years.

A discussion of each type of vegetation monitoring follows.

The analyses do not include discussion of the data collected at sites 5, Family Club or sites 50 and 51, Sunrise Club. These data were not used because these sites were monitored for only a short time, and did not contribute to the long term data analysis.

A. Vegetation Occurrence Data Evaluation

1. Method Description

The Monitoring Agreement (Appendix A) required that “the specific composition of vegetation on lands within 35 meters of each soil water monitoring site will be determined by DFG in August or September of each year. The percent of cover contributed by each plant species present on the sample site will be determined by DFG each year.”

Vegetation adjacent to each soil water monitoring site was surveyed using a variation of the traditional toe-point method as described and implemented by DFG (Briden *et al* 1993). Starting at the soil water extraction tubes, ten readings were taken along each of five randomly selected directional headings. These headings were selected for each site at the beginning of the monitoring program and were used every year to allow comparison of annual sampling efforts. Beginning ten feet from the soil water extraction tubes, one plant species encountered every ten feet was recorded. The overall plant composition was then calculated for the site and recorded as percent occurrence.

2. Data Limitations

The Monitoring Program methodology from the Plan of Protection required that “the percent of cover contributed by each plant species present on the sample site will be determined”. The toe-point method does not measure percent cover, nor does it encounter every plant species present on the sample site.

The toe-point method is modified from the step-point method of sampling (Evans and Love, 1957). The step-point method was originally developed for use in low herbaceous vegetation with fairly uniform structure, like rangelands. To randomly choose between plant species present at each intercept, the surveyor would hold his/her foot at a 30-degree angle to the ground and a pin would be placed in a notch in the boot toe and held perpendicular to the boot. The first plant intersected by the pin was noted as the plant species at that point. When used in the marsh, the notch and pin were not utilized, and the surveyor made a subjective choice of which plant species present at the boot toe to record for each point. The selection of plant species to record was not necessarily the visual dominant at the sampling point. This survey method is inappropriate for vegetation with non-uniform canopy height like that present in the marsh.

The toe-point method is one of several ways to estimate percent occurrence or frequency. Frequency is the percentage of total sampling points that contain at least one individual of a given species. Frequency is a more artificial statistic and has less biological significance than cover or density because frequency estimates will vary according to sampling design, plant distribution, and surveyor bias. Plant cover and density measurements give a clearer picture of how vegetation patterns change over time.

The limited scope, incompleteness, and bias of the data collected make it inappropriate to assign a quantitative measure of vegetation trends. It also complicates the assessment of management effects and soil SC on vegetation. In addition, vegetation in the vicinity of the soil tubes was not necessarily representative of vegetation in the entire pond.

Because of limitations in the method, the data recorded cannot be used to determine percent cover, species abundance, or frequency of occurrence of plant species.

3. Vegetation Occurrence Data Results

The vegetation occurrence data are limited both in scope and accuracy; therefore it is difficult to infer relationships between vegetation and factors such as soil water SC or flood duration. Specific site by site analyses are found in the appendices, and qualitative results are discussed below.

a. Temporal trends

Two methods were used to look for trends in the sampled vegetation over time. Initially, the data from each site were examined for obvious changes in vegetation from year to year. Secondly, a subset of sites, with full data sets for water years 1985-1992, were analyzed statistically for changes in vegetation.

There were 49 sites that had four or more years of vegetation data, and some trends were apparent. It is important to note that because data were collected in a limited area of the pond, trends in the data collected do not imply trends in the vegetation throughout the pond. Of the 49 sites, 20 had fairly stable vegetation occurrence throughout the monitoring period. Fourteen sites became increasingly vegetated by salt tolerant species; usually alkali bulrush gave way to pickleweed, salt grass, and/or bare ground. Ten sites fluctuated substantially from year to year, with no apparent temporal trend. Five sites were fairly stable, with one or two anomalous years.

There were 22 sites that had complete vegetation data for the years 1985-1992. Analysis of variance was conducted on these pooled data to determine if vegetation had changed significantly over the monitoring period. The only plant species that changed significantly were alkali bulrush and pickleweed (98% confidence level). Overall pickleweed occurrence at these sites increased and alkali bulrush decreased. This analysis is significant for the sampling points only, and may or may not be representative of the whole pond.

b. Management effects

The pond stage recorders were the only means to collect information on water management actions, so only the sites adjacent to the recorders (sites 2, 7, 9, 14, 20, 26, 28, 34, 35, 37, 38, 43, 47, 48, and 49) and that had four or more years of data were examined for management effects on vegetation.

Morrow Island.   At site 2, monitored from 1985-1992, flood duration ranged from 136 – 259 days, and was usually about 200 days. Variations in vegetation did not appear to be directly related to flood duration, except during 1987 when site 2 was flooded for only 136 days, causing the young alkali bulrush plants to wither and die. This short flood duration was appropriate for fat hen however, and it dominated the surveyed vegetation. 1987 was the only year that fat hen represented a large percentage of the surveyed vegetation at this site. Leaching occurred at site 2 during 1985, 1987, 1990, and 1991, and did not have an observable effect on vegetation occurrence.

Tule Belle. Management at site 7 was monitored from 1991-1995. Vegetation was primarily pickleweed and sea purslane, which are both salt-tolerant species. Changes in occurrence of these or other species did not appear to be related to annual changes in water management.

Site 9, monitored from 1985-1991, was situated in a low area of the pond that was not well drained, and evaporation of ponded water caused soil water SC to be very high. Neither changes in flood duration or leaching mitigated the effects of high soil water SC and vegetation at site 9 was always about half pickleweed and half bare ground.

Teal.   Water management at site 14 was monitored from 1985-1992 and was fairly consistent. Flood duration was usually long (200-365 days), and leaching was not part of the annual management regime. Soil water SC was always over 20 mS/cm, and this high soil water SC was probably the factor most responsible for the vegetation at this site, which was primarily pickleweed and bare ground.

Island Club. Site 20 was monitored from 1985 to 1991 and from 1993 to 1995. Unfortunately, between 1991 and 1993, there was a substantial change in the vegetation, and since there was no monitoring in 1992, the causes of the change are unknown. From 1985-1991, the vegetation sampled was a fairly stable mix of alkali bulrush, salt grass, and fat hen. During this time flood duration ranged from 115-205 days, and leaching was done every year. From 1993 to 1995, there was very little alkali bulrush at site 20, even though water management was much the same as in previous years.

Gum Tree. Management at site 26, monitored from 1985-1991, was fairly stable from year to year; flood duration ranged from 180 – 223 days, and abbreviated leach cycles were only done in 1985 and 1988. Soil water SC increased from about 20 mS/cm in 1985 to about 40 mS/cm in 1991. During this time, pickleweed dominated the sampling points, alkali bulrush gradually dropped out of the vegetation sampled, and bare ground increased. These changes in vegetation are consistent with the increasing soil water SC.

Grizzly King. Management at site 28 was monitored from 1985-1992 and was fairly stable; flood duration was usually about 200 days (162-245 days), and at least one quick leach cycle was done every year except 1991. Soil water SC increased from about 10 mS/cm in 1985 to 25-30 mS/cm in 1988, and alkali bulrush declined markedly in 1987. Fat hen increased for a few years after the sharp decline in alkali bulrush. After 1988, the sampling points were strongly dominated by pickleweed. This change from alkali bulrush to pickleweed is consistent with an increase in soil water SC, but it is not known why the decline in alkali bulrush preceded the increase in SC.

Sprig. The pond stage recorder was located between sites 34 and 35 and collected data from 1985-1992. Vegetation at both sites was primarily alkali bulrush and pickleweed. Pickleweed increased gradually over time at site 34, but bulrush occurrence was fairly stable at both sites. Flood duration was usually long (233-283 days), which is more favorable to bulrush than pickleweed. Leaching was done only in 1985. Soil water SC increased over time at both sites, from about 10 mS/cm to about 30 mS/cm.

Grizzly Island.   Site 37 was monitored from 1988-1991, and during this time, no leaching was done and flood duration was highly variable, ranging from 164 to 302 days. Spring soil water SC was fairly stable at about 15 mS/cm, but fall and summer SC was usually between 40 and 60 mS/cm. There was no clear-cut relationship between water management and vegetation. Alkali bulrush was most prevalent in 1989 when flood duration was 302 days, and appeared to decrease in 1988 and 1990 when the flood duration was around 160 days. However, it remained fairly low in 1991 when the flood duration was 238 days.

Site 38 was monitored from 1985 to 1990, and flood duration was always less than 173 days except in 1989 when it was 245 days. Alkali bulrush was most prevalent at the sampling points in 1989, probably due to the longer hydroperiod. Soil water SC was not high at this site (spring SC never exceeded 20 mS/cm), but pickleweed was usually the most commonly encountered plant during annual surveys.

Water management at site 49 was monitored from 1992 to 1995. Flood duration was around 200 days in 1992 and 1993, around 110 days thereafter. Leaching was done all years but 1992. Vegetation changed from year to year but was not obviously related to water management.

Mallard. Water management at site 41 was monitored from 1985 to 1989. No leaching was done, and flood duration was usually between 170 and 210 days, except in 1986 when leaching was done in July and flood duration was 252 days. It appears that this change in management affected the vegetation, because alkali bulrush dominated the sampling points only that year. Soil water SC increased over time and pickleweed became more prevalent as SC increased.

Water management at site 43 was monitored from 1990 through 1992. Flood duration ranged from 172 to 210 days, and one leach cycle was done in 1990. The site was dominated by pickleweed throughout this time.

West Family. Water management at site 47 was monitored from 1986 through 1995, but the club was closely managed from 1968. Leach cycles were conducted almost every year, and spring soil water SC rarely exceeded 20 mS/cm. Control of soil water SC kept this pond well vegetated with many species and an abundance of fat hen and alkali bulrush. Management tended to alternate between early drawdown (promotes fat hen) and late drawdown (promotes alkali bulrush), and although occurrence of these species did not always reflect the management regime (e.g. bulrush dominated in 1991 when early drawdown was used, and vice versa in 1994), one or both of these species were always commonly surveyed at site 47.

Goodyear. Perhaps more than any other ownership in the monitoring program, Goodyear illustrates the consequences of poor water management. During 1986 and 1987, the pond was managed under the early drawdown regime, and fat hen dominated the sampling points. Soil water SC was held in check at about 25 mS/cm. During an ownership transfer in 1988, the pond was not managed, and soil water SC doubled to more than 50 mS/cm, and pickleweed and bare ground replaced the fat hen. Once water management resumed, the early drawdown regime was not used, and soil water SC remained high and pickleweed continued to dominate the pond.

For a more detailed comparison of water management, soil water SC, and vegetation at Goodyear and West Family, see Chapter XI, Management.

c. Soil water SC effects

Of the 13 sites with steadily increasing soil water SC trends (sites 2, 4, 6, 8, 10, 11, 15, 16, 25, 26, 32, 34, 35), the majority did not show any consistent trends in vegetation sampled around the soil sites. It would be expected that as soil water SC increased, vegetation would tend toward plants that are more salt tolerant such as fat hen, salt grass, sea purslane, or pickleweed. However, most of the sites with increasing soil water SC did not show an increasing trend in these plants, or a decrease in plants that are less salt-tolerant, such as alkali bulrush. Only four of these thirteen sites (sites 2, 6, 25, and 32) showed obvious trends toward more salt tolerant plants.

Site 2, Morrow Island. The area around site 2 was almost entirely alkali bulrush during 1985 and 1986. From 1987 to 1992 vegetation changed from year to year, with pickleweed, fat hen, and bare ground replacing much of the alkali bulrush.

Site 6, Tule Belle. The sampling points around site 6 were dominated by alkali bulrush in 1985 and 1986, but by 1991 pickleweed dominated and there was very little alkali bulrush.

Site 25, Gum Tree. At site 25, alkali bulrush steadily decreased, while salt grass and bare ground slowly increased. Pickleweed was the most commonly sampled plant at this site every year.

Site 32, Sprig. At site 32, pickleweed increased from 1985 to 1987 and then stayed fairly stable through 1992. However, there was no significant change in alkali bulrush during this time.

The vegetation and soil water SC data were examined site by site to determine if annual changes in soil water SC resulted in vegetation changes. In some cases, increases in soil water SC were followed by increases in salt-tolerant plant species, however there are many other cases where significant annual increases in soil water SC did not appear to affect the vegetation sampled. Since the results are mixed, it does not appear that soil water SC alone is responsible for changes in vegetation. It is also likely that limitations of the vegetation sampling method prevent accurate correlations from being made.

3. Conclusions

It is not known how well the data collected represent the actual vegetation around the soil water SC tubes, or in the pond as a whole. This lack of confidence in the data makes it difficult to draw significant conclusions about the vegetation, or about the factors that affected the vegetation occurrence.

The data were highly variable from site to site, consistent with the variability in the pond and soil water SC data. This variability increases the difficulty of drawing conclusions about the relationship between vegetation occurrence and factors such as soil water SC and flood duration.

It is apparent that water management has a significant effect on vegetation. However, the data collected are inappropriate for quantifying the relationship between management actions and vegetation. Changes were evident (as at Goodyear) from gross changes in management, but more subtle or short-term changes did not produce predictable results.

4. Recommendations

Rather than extrapolating the species occurrence from 50 non-random samples, a visual estimate and rough mapping of the vegetation within 35 meters of the soil tubes would provide a more complete (and fairly quick) survey of the vegetation. Coupled with plot or transect sampling of cover and density, this method would provide a more accurate determination of the species composition around the soil tubes. Qualitative information on the condition of the vegetation should also be recorded.

The vegetation throughout the pond should have been sampled in addition to that within 35 meters of the soil water tubes. By collecting data only at the tube sites, the analysis of effects of water management on vegetation may be affected by microsite variations.

It is apparent that there are numerous factors that contribute to the health and abundance of plants in a managed pond. It would be invaluable to have records of specifics such as when gates were opened, applied water SC at time of gate opening, when circulation occurred, when drainage commenced, whether gates and drains were operating properly, when and where discing, burning, or ditching were done, and general observations from a manager who is familiar with the topography, hydrology, and vegetation of the pond.

B. Vegetation Production Data Evaluation

Seed production of alkali bulrush was an important factor in establishing the D-1485 water quality standards and the on-site monitoring program. The D-1485 Suisun Marsh standards were set to be the "salinity of applied water required to achieve an average of 90% of maximum alkali bulrush seed production and 60% seed germination" (Rollins 1981). One of the goals of the on-site monitoring program was to assess how applied water salinity and soil water salinity affected alkali bulrush and fat hen seed production.

1. Method Description

The Monitoring Program Methodology from the Plan of Protection states that "seed production. . . immediately adjacent to each soil water monitoring site. . . will be measured by clipping the seed heads from all plants contained within a square-meter plot. . . and the weights of cleaned seed. . . reported in pounds per acre". To meet this requirement, seed production weights have previously been reported in pounds per acre. However, the conversion of a single grams/m^2 weight to pounds/acre gives a misleading estimate of the seed or biomass production. Therefore, for this Comprehensive Review, the data are reported as they were collected, in grams/m^2.

There are no production data available for 1991 because the original grams/m^2 data could not be found, and there were doubts about the accuracy of the existing pounds/acre data. The previously reported pounds/acre data for 1992 are incorrect, because the wrong multiplier was used in converting the data from grams/m^2.

At the late drawdown ownerships (extraction tubes at the 6 inch depth only), alkali bulrush seeds were collected each August or September to estimate production. Seeds were collected by clipping seed heads from all alkali bulrush plants growing within a single one-square-meter area near the soil water extraction tubes. The meter-square area was selected for a high density of alkali bulrush stems and large quantity of seed heads.

Seed heads were air dried, and the seeds were separated out and weighed on a Mettler balance to the nearest tenth gram.

At the early drawdown ownerships (soil extraction tubes at 6, 18, and 30 inch depths), fat hen samples were collected by clipping all fat hen above ground level within a single one-square-meter area near each soil water extraction site. The meter-square area was chosen for a high density of fat hen. Samples were air dried and weighed to the nearest tenth gram without attempting to separate fat hen seeds from other vegetative parts.

2. Data Limitations

Although the method used was that mandated by the Suisun Marsh Monitoring Agreement, it does not provide an accurate estimate of plant production in the area around the soil monitoring sites and it cannot be used to evaluate whether the monitored ownerships in the marsh achieved the seed germination and production goals upon which the D-1485 standards were based. The method of data collection limit the usefulness of the data for the following reasons:

- It is unclear whether the data were to estimate the production in the area around the soil monitoring site or over the entire pond. The methodology states that the estimate was for the area within 35 meters of the soil water monitoring site, but this area is much smaller than one acre, so the pounds/acre result is misleading.
- The use of a single sample cannot provide an accurate estimate of seed production. Multiple samples are needed to obtain a statistically significant result.
- The use of a non-random sample chosen for high density of the target plant species overestimates actual production. Random or stratified-random selection techniques should have been used to determine the location and number of sample sites.
- To accurately estimate production in the area around the soil water monitoring site, the plant production data should have been correlated with the plant occurrence data. Aerial photos or ground mapping should have been used to determine the actual occurrence (square meters or acres) of the target species and then estimate production in weight per total area of the target species.

A more accurate method of measuring production would require estimating percent cover of the target species of interest and taking random samples of seed heads or biomass within several different stands of that species.

Table VII-1. Results of alkali bulrush seed production measurements, in grams/meter^2.

club	site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Morrow-	1	62.6	11.9	35.3	158.0	NA/3	27.2		28.4			
Island	2	60	58.0	NA/1	113.6	0	NA/2		NA/3			
	3	10.5	14.5	0	30.9	0.1	18.2					
	4	25.3	61.2	0	156.8	0.1	72.6		0.2			
Tule-	6	5.6	46.7	1.3	0	0	1.5					
Belle	7	60	94.1	22.4	114.2	307.6	NA/3		1.1	43.3	40.8	3.6
	8	40	65.9	6.5	289.9	0	18.6					
	9	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2					
	10	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2					
Teal	11	NA/1	101.4	<0.1	2.6	179.2	NA/3					
	12	12	1.2	3.2	0	35.0	NA/3		0.4			
	13	18.9	0.9	0.7	<0.1	14.6	0		1.6			
	14	2.5	<0.1	NA/2	NA/2	NA/2	NA/2		NA/3			
Joice-	15	NA/2	1.0	<0.1	0.0	90.2	NA/3					
Island	16	2.9	217.5	0.7	9.4	NA/3	NA/3					
	17	1	5.4	0.1	0	0	108.8					
	18	1.2	9.9	<0.1	0	1.7	1.8					
Island	19	97.7	35.7	1.0	0	154.1	5.5		4.8			
	19a									39.4	16.8	16.7
	20	NA/2	18.4	13.4	0.1	32.5	117.9		NA/1	106.3	38.9	82.7
	21	128.3	24.1	1.0	<0.1	159.3	0		1.6			
	22	46.4	92.9	1.9	0	23.0	12.7		1.7			
Gum-	23	30.5	116.1	0.2	0.4	8.9	NA/3		1.7			
Tree	24	55.8	42.6	0.1	5.0	0	NA/3		0.1			
	25	55.6	3.2	4.0	14.6	0	NA/3					
	26	21.8	3.7	NA/2	4.1	0	NA/3		0			
Grizzly-	27	NA/2	4.1	NA/2	NA/2	NA/2	NA/2					
King	28	NA/2	3.6	3.6	0	74.2	NA/2		0			
	29	320.6	138.4	NA/2	NA/2	NA/2	0.6					
	30	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2		NA/2			
Sprig	31	58.4	18.7	2.6	37.3	13.4	0.4		5.4			
	32	118.4	138.6	31.8	37.5	9.0	0.6		93.2			
	33	26.4	27.9	19.7	53.2	2.9	0.2		177.9			
	34	124.3	116.5	18.4	68.5	38.5	9.1					
	35	80.3	61.4	11.4	71.0	37.5	NA/3		82.8			
Grizzly-	36	3.8	1.3	<0.1	0.0	92.0	81.6		0.0			
Island	37	68.8	0.4	1.2	0.0	127.7	NA/3					
	38	57.2	0.2	2.2	0.0	156.9	NA/3		0.0			
	39	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2		0.0			
	40	46.7	62.3	77.3	154.3	28.0	3.2		0.9			
Mallard	41		0.0	18.4	7.1	0.6	0.4		3.0			
	42		<0.1	NA/2	0.0	0.2	0.6		2.5			
	43			<0.1	1.5	0.1			0.0			
	44				0.0	0.7			0.8			
	45	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2	NA/2			

1/Data not collected.
2/No alkali bulrush.
3/Site mowed, disced, or flooded and production could not be measured.

3. Vegetation Production Data Results

The alkali bulrush seed production and fat hen biomass production results are shown in tables VII-1 and VII-2, respectively. Individual graphs of the production at each site are in the appendices.

Mall (1969) found that alkali bulrush seed production was a function of soil salt concentrations in May, and flood duration. Mall found that the optimal conditions for high seed yield were May soil water SC level between 7-14 ppt, and soil submergence of more than six months. The results of the on-site monitoring program could not substantiate these results. Table VII-1 shows that alkali bulrush seed production varied widely from year to year and from site to site. No site had consistently high seed production every year. The seed production data were compared to both flood duration and spring soil water SC, and no correlation was found in four different tests: (1) all the data points for all sites; (2) data from all sites for the years when seed production was low (<100 lb./acre) or high (>500 LB/acre); (3) for sites that had five or more years of data and averaged less than 10 g/meter or averaged more than 50 g/meter; and (4) for all sites where alkali bulrush was the dominant vegetation sampled. There were many sites that achieved appropriate flood duration and soil water SC but had zero alkali bulrush seed production, and other cases where soil water SC and flood duration were not optimal but seed production was high. As with soil water SC, there are apparently several factors involved in seed production.

There were only four sites that were monitored for fat hen (Table VII-2). There was also no correlation found between fat hen biomass production and either flood duration or May soil water SC.

Table VII-2. Results of fat hen biomass measurements, in grams/meter^2.

club	site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
West Family	46	NA[1]	NA[2]	712.0	146.0	751.9	916.0	2021.2	2094.9	395.7	828.2	421.8
	47	NA[1]	NA[2]	1442.0	641.0	1583.8	1333.2	2138.0	1496.4	446.2	1423.1	333.9
Goodyear	48	NA[1]	NA[2]	1592.0	327.0	692.9	489.8	491.8	3047.2	386.8	513.8	NA[3]
Grizzly Isl	49	NA[1]	NA[2]	921.1	301.0	876.9	639.4	3091.7	625.8	215.6	725.1	483.0

1/Site not yet established.
2/Fat hen sample processing techniques were unsuccessful in separating seeds. No data collected.
3/Site was flooded and production could not be measured.

4. Conclusions

The data analyses show that the data collected cannot be statistically correlated to either May soil water SC or flood duration. Rollins (1981) and recent DFG management (Cann 1997 personal communication; see Notes at end of chapter) have shown that water management can lead to dominant stands of alkali bulrush or fat hen. However, results of this monitoring program indicate that seed and biomass production do not appear to be dependent upon flood duration or May soil water SC.

5. Recommendations

Seed and biomass samples should be collected from multiple, random sites across the pond. Percent cover of target species should also be estimated for the entire pond. These measurements would allow for a more accurate estimate of actual seed production.

The monitoring program was not successful at separating fat hen seeds from vegetative biomass. Fat hen is an annual plant dependent upon seeds for reproduction, and an actual seed measurement would have provided more accurate data about the quantity of available waterfowl food.

The plant production data were collected to help address relationships between water management and vegetative production. It appears, however, that the data collected in this monitoring program were not appropriate for addressing these questions. As with soil water SC, multiple factors affect the vegetative production, and this monitoring program did not have sufficient controls to determine the individual effects of multiple factors.

C. Tri-ennial Vegetation Survey Data Evaluation

1. Method Description

The Monitoring Program methodology from the Plan of Protection required that "the overall vegetative composition of the marsh shall be determined every third year utilizing color aerial photography in conjunction with ground verification. The results...will be compared to the results from past flights and will be reported in acres and percent of total vegetation for each major plant species". These surveys were completed in 1981, 1988, 1991 and 1994.

For each survey, aerial photographs of the marsh were taken during a low tide in June and 9 by 9-inch color prints provided at a scale of 1 inch to 800 feet. Prior to ground truthing, each aerial photograph was examined using a magnifying lamp, and areas of similar color, pattern, and texture were outlined. Within each vegetation type the number and length of transects necessary for ground truthing was determined by the size and homogeneity of the area, and ranged from 1 - 30.

Ground truthing occurred during the summer months. On each transect, the type of vegetation encountered at five meter intervals was determined using the toe-point method described above in the Vegetation Occurrence section. For each transect, the vegetation composition was entered as a percentage for each species encountered. These percentages were then applied to areas of similar appearance in the aerial photos. The acreage of each vegetation type was determined using a planimeter. Acreage of the vegetation types was then multiplied by the percent occurrence of the species within the habitat to determine the acreage for individual species on each photo. Acreage values for each species were summed from all of the photos.

In addition to monitoring vegetation change across the marsh, the Triennial Survey was supposed to monitor the acreage of preferred salt marsh harvest mouse habitat (for details see Salt Marsh Harvest Mouse section, below). To assist in this, the marsh was divided into five zones to decrease the potential for significant local decreases in habitat being masked by increases in other areas of the marsh. These zones were established prior to the 1981 survey, and were to be used to analyze vegetation changes in each subsequent survey. However, they have not been used for their original purpose of assessing changes in preferred salt marsh harvest mouse habitat. In addition the triennial survey was to be compared with annual vegetation monitoring transect data from the 1000 acres of salt marsh harvest mouse habitat. The aerial photo interpretation and companion annual on-the-ground vegetation monitoring were not implemented.

For the 1994 survey, ground truthing was done before the aerial photos were available to field personnel. In ponds selected for sampling, a visual estimate was made of the number of habitat types within the pond. Transects were run through each habitat type using the toe-point method. Transect locations were marked on topographic maps and later transferred to the aerial photos. Data from the transects were used to first delineate habitat types on the photos, and then determine percent occurrence of individual species within the habitat type.

2. Data Limitations

The Plan of Protection required that results "be reported in acres and percent of total vegetation for each major plant species", but this is not an accurate method to describe the vegetation in the marsh. While it is possible to determine precise acreages of species of concern, methods used in this program do not result in information at this level of detail. Determination of individual species composition marsh-wide would require an extremely intensive sampling effort with rigorous replication to report data at the species level with any degree of certainty. Marsh habitats are often mixed assemblages of several species rather than monotypic stands. To lump percentages of species within each habitat into single species categories loses the character of the habitat.

The limitations of the toe-point method are discussed in detail in the Vegetation Occurrence section above. This method was not designed for use in multi-layered habitats, and as employed, introduced a significant level of surveyor bias, and did not include necessary replication to determine sample variance and certainty of ground-truthing. It is not an appropriate method for detecting all the species present in the habitat, or for determining the cover or density of species within the habitat. Thus, the bias and incompleteness of the data, coupled with grouping of the data into single species categories, did not result in an accurate representation of the vegetative composition of the marsh.

The five zones established in the marsh have not been used for their original purpose of assessing changes in preferred salt marsh harvest mouse habitat. In addition, the triennial survey was to be compared with annual vegetation monitoring data from the salt marsh harvest mouse conservation areas. The aerial photo interpretation and annual vegetation monitoring were not implemented. Although the marsh-wide vegetation surveys measured the acreage and percentages of pickleweed, there were no surveys for preferred salt marsh harvest mouse habitat, and it has not been possible to assess changes in acreage of preferred habitat. In addition, because the vegetation was categorized by species rather than habitat type, the actual acreage of pickleweed-dominated habitats cannot be determined by the survey results.

3. Tri-ennial Vegetation Survey Data Results

It is essential to note the limitations discussed above. The results of the surveys are listed here, but this does not imply that these findings are accurate or precise. The results are not discussed here, partly due to the limitations of the data, but also because there are no maps, essential to any discussion of vegetation trends, and because of limitations of space. The DFG has prepared a draft report of these results, but it has not yet been released as a final document.

The results of the vegetative surveys since 1981 are shown in tables VII-3 and VII-4. Table VII-3 lists the 13 classifications that were used in the analysis and gives the number of acres of each type that were delineated from the aerial photos. Table VII-4 lists the same 13 classifications with the percentage of total ground cover that each represented. These tables should be used only to give a broad sense of how vegetation changed from year to year.

Table VII-3. Results of Suisun Marsh vegetation surveys 1981-1994, in number of acres for each vegetation type.

Veg type	1981	1988	1991	1994
Pickleweed	12,745	12,581	10,243	15,412
Alkali bulrush	14,088	6,931	5,964	3,838
Olney bulrush	48	978	534	1,273
Cattail/Tule	6,954	5,282	5,510	5,572
Brass buttons	3,809	1,588	3,529	2,676
Fat hen	444	297	562	1,497
Saltgrass	4,447	8,862	8,647	4,650
Baltic rush	140	1,272	1,242	1,445
Sea purslane	22	314	164	1,784
Annuals	26,401	21,490	18,567	21,044
Bare ground	3,913	5,230	8,111	3,018
Open water	3,908	5,487	8,038	7,259
Miscellaneous	1,520	8,127	7,322	8,970
TOTAL	78,439	78,439	78,434	78,438

Table VII-4. Results of Suisun Marsh vegetation surveys 1981-1994, in percent of total for each vegetation type.

Veg type	1981	1988	1991	1994
Pickleweed	16.2	16.1	13.1	19.6
Alkali bulrush	18.0	8.9	7.6	4.9
Olney bulrush	<0.1	1.2	0.7	1.6
Cattail/Tule	8.9	6.7	7.0	7.1
Brass buttons	4.8	2.1	4.5	3.4
Fat hen	0.6	0.4	0.7	1.9
Saltgrass	5.7	11.3	11.0	5.9
Baltic rush	0.2	1.6	1.6	1.8
Sea purslane	<0.1	0.4	0.2	2.3
Annuals	33.7	27.3	23.7	26.8
Bare ground	5.0	6.6	10.3	3.8
Open water	5.0	7.0	10.2	9.3
Miscellaneous	1.9	10.4	9.3	11.4
TOTAL	100	100	99.9	100

4. Conclusions

Concerns about the methodology used and the lack of useful maps from past surveys led to a change in methodology. Additional limitations of the past methodology included not using a habitat classification system such as that used in the California Habitat Relationship System, assessing acreages of individual species rather than vegetative assemblages, and using inappropriate methods for calculating the acreages of each vegetation type. In 1996, a multi-agency (DFG, DWR, USBR, USFWS, and SRCD) technical committee convened to review the current survey methodology and recommended a more detailed monitoring system for vegetation changes within the marsh. Consequently, in July 1997 the committee agreed to implement a new survey methodology for the next vegetation survey, to be conducted in the summer of 1999.

5. Recommendations

Recommendations were submitted to the multi-agency technical committee in 1996. The new methodology and protocol has addressed the concerns about the limitations of past surveys. Further recommendations may be made after receiving the results of the 1999 survey.

a. Methods for Vegetation Sampling and Classification

The vegetation map will be based on collected field data and analysis of these data. A Vegetation Sampling Protocol developed by the California Native Plant Society (CNPS) Vegetation Committee will be used for this project.

The CNPS sampling method uses variable sized releve plots centered in representative vegetation stands based on aerial photograph delineations. The number of samples per

vegetation stand are determined in the field and depend on the size and floristic variability of the stand, the time available to the field team, and the proximity of other stands of the same vegetation type. The percent cover for each species is estimated according to vegetation strata
(low herbaceous cover, shrub, and tree).   Global Positioning System (GPS) readings are taken at the center of each sampling plot and used to produce a GIS coverage of the vegetation sampling locations.

Although the sample allocation protocol used in this project will stress representation of all forms of vegetation in the project area, particular attention will be given to SMHM set-aside areas and known Clapper Rail sites. These sites will be allocated additional vegetation samples to assist in monitoring the correlations between vegetation dynamics and population data collected in on-going studies in the areas.

The field collected vegetation data will be entered into the California Vegetation Information System (CVIS), a database designed specifically to archive vegetation plot data. This database accommodates all information recorded at field sampling locations, including impacts, abiotic environmental data, and ecological information.

b. Methods for Constructing the Vegetation Map

The vegetation map will be constructed through the interpretation of aerial photographs, field investigations, vegetation classification, and GIS processing. Vegetation throughout the project area will be sampled and characterized during field visits. The resulting information will be analyzed using hierarchical classification techniques (TWINSPAN)(Hill 1979) to develop a vegetation classification which lists and describes the vegetation types within the boundary area. Polygons will be assigned final vegetation attributes and transferred to the GIS through a process which involves digitizing vegetation polygons, georeferencing the data, and editing the data for quality control.

c. An Adaptive Approach to Repeat Mapping

One of the outcomes of this new proposed methodology will be a responsive means to determine the need for repeat survey and mapping of Suisun Marsh. Under the current agreement with DWR and USFWS, DFG is to re-survey and map the entire marsh every third year. As a result of the short-term inconsistency of both natural and non-natural disturbance patterns, it is likely that the justifications for re-survey will vary significantly from year to year. Thus, we propose a rapid assessment protocol conducted on a yearly basis to determine the need and timing for a complete re-survey.

We suggest that aerial photographs of the marsh should be flown on a yearly basis stressing phenological congruence (flown at the same growth stage every year). These photographs would be checked for the overall percent of polygon change by a trained photo-interpreter. Polygon change can be quantified as major (e.g., gross vegetation shift, major flooding, or human disturbance) or minor (slight shifts in polygon boundaries due vegetation growth, die back, or minor human disturbance). A statistically significant sample size of polygons throughout all vegetation types in the marsh would be randomly selected from the vegetation map database. These could be compared by observing new photos with overlays of the most recently produced map (with the highlighted selected polygons for ease of comparison). If the percentage of polygons in the sample showing a major change was greater than a certain percent for any given year, or a certain cumulative percent for any given multi-year period then a resurvey would be conducted. The threshold value of percent change would be agreed upon by the managers and the survey team (we suggest a resurvey if change is greater than 10% on an annual basis or greater than 30% in three or more years, cumulatively).

Under such a regime, resurvey could occur regularly after a major environmental disturbance over a period of years, or may not occur for several years during a stable phase.   It is likely that additional information based on independent sampling of SMHM populations should be considered in the decision to re-survey. Based on consultation with biologists familiar with population dynamics of this species a specific threshold could be developed. In addition, inquiries of land managers should be made to determine what, if any, management shifts are expected to take place that might warrant re-survey.

This adaptive approach would likely reduce the cost of the project but would require a regular photographic survey and rapid assessment change-detection every year. Personnel time would be approximately 10 days a year for statistical selection and plotting of polygons by a GIS analyst, six days for ecologists to train a photointerpreter scientific aid and report results, and approximately 50 days for the scientific aid to conduct the change detection.

Notes

Cann, J. (California Department of Fish and Game, Grizzly Island Wildlife Area). 1997 conversation with P. Finfrock, Department of Water Resources, Environmental Services Office)

Chapter VIII
Waterfowl Surveys

A. Waterfowl Survey Data Evaluation

1. Method Description

Suisun Marsh waterfowl are censused each year from September to January by aerial surveys conducted by DFG. During the survey, the plane is flown 100 to 150 feet above the ground at a speed of 90 to 105 miles per hour (USFWS 1987). Observers estimate the number and species composition within 1\8th of a mile on either side of the plane.

2. Data Limitations

These techniques are standard practice for waterfowl surveys. During the Suisun Marsh surveys, standard transects are not flown. The counts are conducted “where the birds are” and these numbers are used to provide a population index. These data are not rigorously collected and are not used for management decisions, but do provide a measure of change in relative distribution between areas (of California) and between years (Yparraguirre 1997 personal communication; see Notes at end of chapter).

The aerial surveys were usually conducted on a hunt day, when the birds tend to accumulate on DFG refuges. Therefore, private lands were not well-represented in the data. Unfortunately, this prevents the data from being used to assess how management and vegetation affect waterfowl usage.

The goal of water management is to attract waterfowl. Therefore, waterfowl surveys of the monitored ownerships would have provided vital information on the link between management, habitat, and waterfowl use. The monitoring program collected data on channel water SC, pond water SC, soil water SC, and water management, in an effort to relate these factors to vegetation. However, no data were collected to relate the vegetation in the ponds to waterfowl usage, which is the primary interest of most land owners.

B. Data Results

The results of aerial surveys in the Suisun Marsh from water year 1986 to 1995 are shown in Table VIII-1 and graphed in Figure VIII-1. These two figures use only the numbers of ducks, because these data sets are more standardized and complete than those for all waterfowl.

Table VIII-1. Numbers of ducks and waterfowl counted during aerial surveys in Suisun Marsh, WY86-WY95.

		Ducks	Waterfowl
Water Year 1986	Sept 1985	32,415	32,435
	Oct 1985	No survey	No survey
	Nov 1985	117,835	117,835
	Dec 1985	96,278	97,994
	Jan 1986	77,440	79,190
Water Year 1987	Sept 1986	37,080	37,080
	Oct 1986	No survey	No survey
	Nov 1986	68,404	68,439
	Dec 1986	98,431	98,518
	Jan 1987		125,955
Water Year 1988	Sept 1987	28,485	29,025
	Oct 1987	No survey	No survey
	Nov 1987	108,489	108,493
	Dec 1987	78,973	79,131
	Jan 1988	37,000	38,486
Water Year 1989	Sept 1988	15,482	15,912
	Oct 1988	No survey	No survey
	Nov 1988	62,919	64,914
	Dec 1988	83,021	84,422
	Jan 1989	91,000	93,567
Water Year 1990	Sept 1989	10,115	10,235
	Oct 1989	No survey	No survey
	Nov 1989	52,900	53,057
	Dec 1989	128,287	130,105
	Jan 1990	134,000	142,992
Water Year 1991	Sept 1990	20,254	20,329
	Oct 1990	35,355	35,355
	Nov 1990	68,622	75,820
	Dec 1990	95,476	100,192
	Jan 1991	146,000	179,246
Water Year 1992	Sept 1991	7,375	7,375
	Oct 1991	50,525	51,702
	Nov 1991	89,212	92,129
	Dec 1991	146,890	159,652
	Jan 1992	78,000	85,229
Water Year 1993	Sept 1992	24,021	24,076
	Oct 1992	56,770	58,470
	Nov 1992	92,977	98,967
	Dec 1992	No survey	No survey
	Jan 1993	85,000	91,386
Water Year 1994	Sept 1993	8,565	9,260
	Oct 1993	85,027	90,442
	Nov 1993	118,685	129,997
	Dec 1993	100,958	119,340
	Jan 1994	62,260	69,627
Water Year 1995	Sept 1994	12,507	12,824
	Oct 1994	125,805	137,382
	Nov 1994	No survey	No survey
	Dec 1994	136,104	141,369
	Jan 1995	37,282	44,648

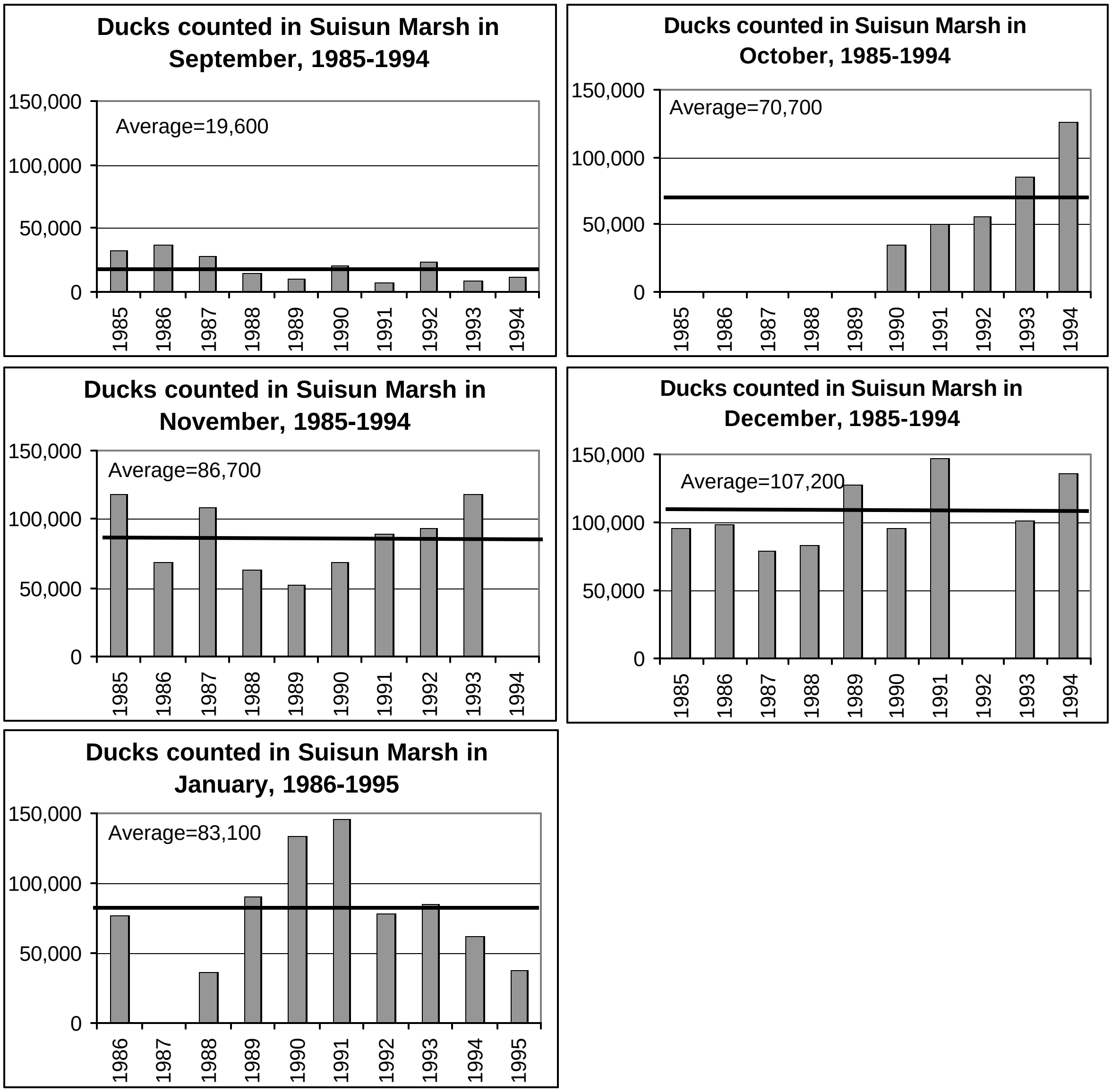


Figure VIII-1. Numbers of ducks counted in Suisun Marsh during aerial surveys, 1985-1995. Heavy horizontal line denotes 10-year average.

Duck numbers were fairly stable during September, November, and December of water years 1986-1995. Numbers were variable during midwinter counts in January, but tended to decline from 1991 to 1995. During this same time period, the numbers of ducks present in October increased.

The January, or Midwinter, count is used for statewide comparison purposes. midwinter counts from California are shown in Figure VIII-2, and for Suisun Marsh in Figure VIII-3. The graphs also include 10-year averages for making simplistic comparisons over time. These averages show that in California, duck numbers were fairly stable from 1956 to 1985, and decreased by almost half from 1986-1995. This statewide decline is attributed primarily to drought conditions in the breeding areas of Canada. Duck numbers in Suisun Marsh, however, declined by more than half in the late 1960's, and then dropped only slightly from 1986-1995. The decrease in the Suisun Marsh population has been attributed to increases in duck use in the Sacramento and San Joaquin valleys, but there have been no studies to substantiate this claim. Data collected by this Monitoring Program are not adequate to address this question.

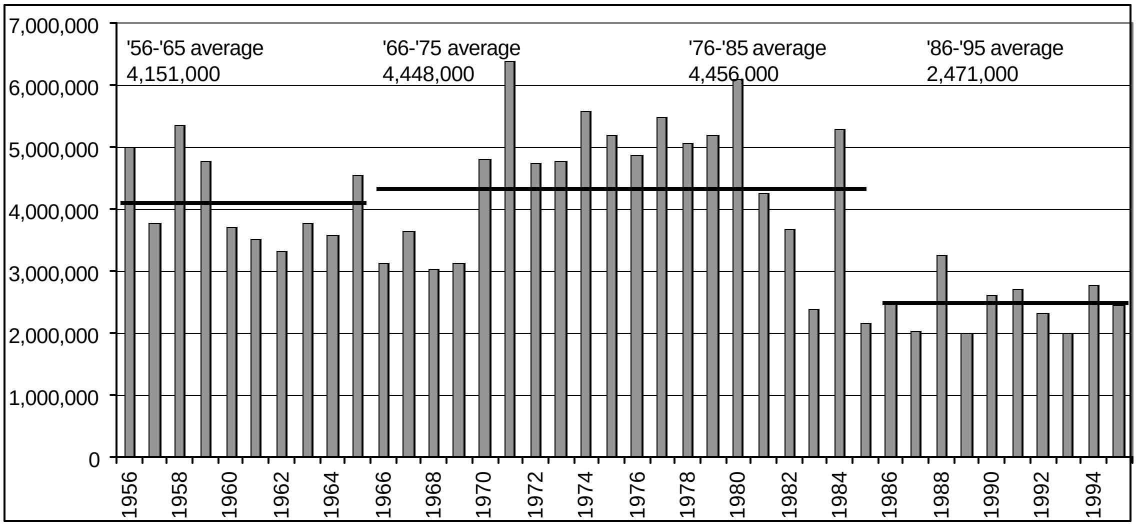


Figure VIII-2. Number of ducks in California during January counts 1956-1995. Heavy horizontal lines denote 10-year averages.

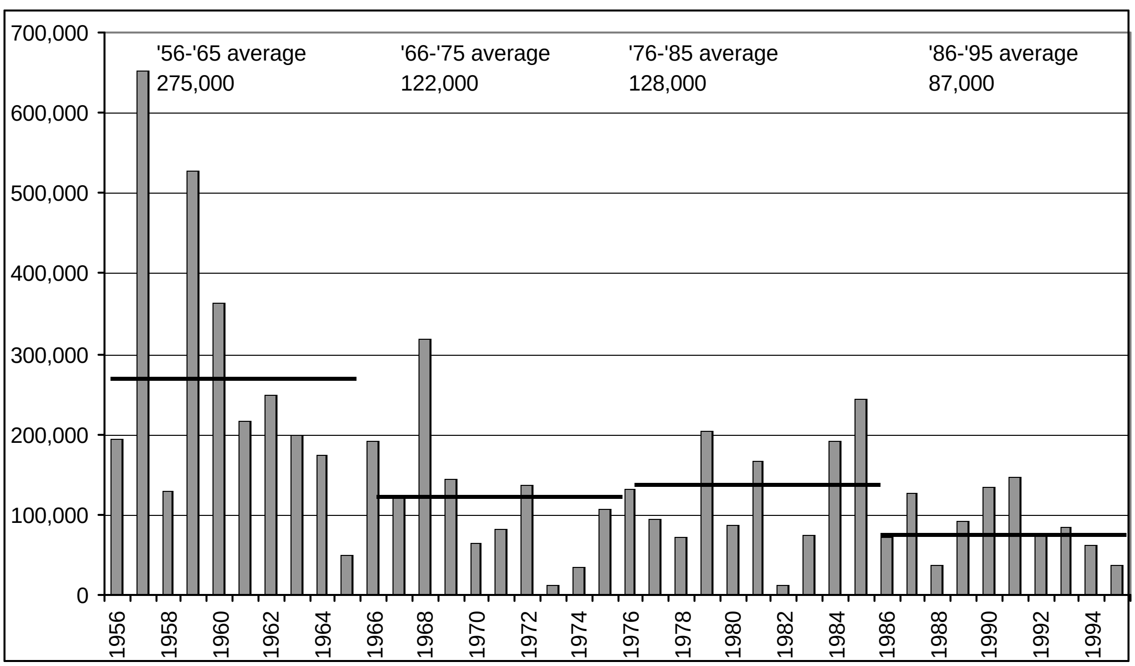


Figure VIII-3. Number of ducks in Suisun Marsh during January counts, 1956-1995. Heavy horizontal lines denote 10-year averages.

C. Conclusions

The methods used are standard methods for aerial waterfowl surveys. Despite the limitations, the surveys are adequate for assessing long term trends in waterfowl numbers and areas of utilization.

D. Recommendations

It is recommended that the surveys continue in the same manner until more detailed data are needed for management decisions or ecological studies. Future studies on management practices or vegetation occurrence on the managed wetlands should include waterfowl surveys of the monitored ponds.

Notes

Yparraguirre, D. (California Department of Fish and Game). 3 December 1997. Email addressed to P. Finfrock, Department of Water Resources, Environmental Services Office)

Chapter IX
Salt Marsh Harvest Mouse Surveys

A. Introduction

The salt marsh harvest mouse (*Reithrodontomys raviventris*) (SMHM) is endemic to Suisun Marsh and the marshes of San Francisco Bay (USFWS 1984). The species was listed as endangered by the U.S. Fish and Wildlife Service in 1970 and the California Fish and Game Commission in 1971.

In 1981, the U.S. Fish and Wildlife Service issued a Biological Opinion for the Suisun Marsh Plan of Protection. In the Opinion, the U.S. Fish and Wildlife Service expressed concern that the implementation of the Plan of Protection and more intensive management practices on both State and private wetlands could result in reduction of preferred SMHM habitat. To compensate for this potential loss, the U.S. Fish and Wildlife Service required the DFG to provide 1,000 acres of marshland as preferred SMHM habitat, toward a long-term goal of retaining “2,500 acres of preferred SMHM habitat adequately distributed throughout the marsh” (USFWS 1981).

The DFG set aside seven areas totaling more than 1,000 acres of State land in Suisun Marsh to fulfill this requirement. Figure IX-1 shows the seven conservation areas plus Peytonia Slough Ecological Reserve. The DFG prepared a management plan for the conservation areas that included: (1) water and habitat management of areas designated as SMHM conservation areas, (2) future acquisitions of SMHM habitat, (3) monitoring to establish baseline conditions of the seven conservation areas, (4) ongoing monitoring of the vegetation and SMHM populations of the seven areas including annual surveys along permanent vegetation transects and SMHM surveys every three years in conjunction with a triennial vegetation survey and (5) project review (Wernette, 1987).

The Monitoring Program methodology from the Plan of Protection required that the marsh-wide aerial photo survey for the tri-ennial vegetation survey also “be used to monitor the extent of preferred SMHM habitat”. The Biological Opinion for the Plan of Protection states: “Current pickleweed areas will be mapped using the planned 1981 (vegetation survey) flight. Ground truthing will then be used to determine the approximate acreage of preferred SMHM habitat that meets the density, height, and condition requirements...A change in preferred SMHM habitat will be significant when the acreage decreases by one-third in any [one of five] zone (based on data from ground verification of the 1981 flight).”

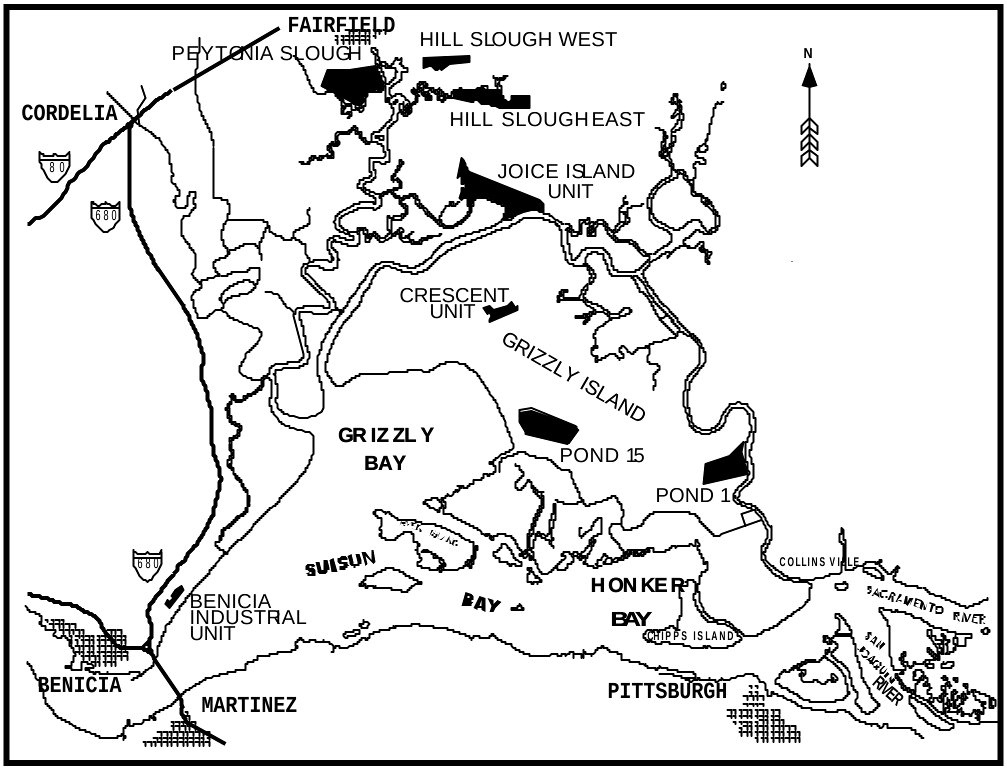


FIGURE IX-1. Department of Fish and Game Lands Designated as Salt Marsh Harvest Mouse Conservation Areas.

B. SMHM Data Evaluation

1. Method Description

SMHM were surveyed with Sherman live traps baited with a mixture of bird seed and ground walnuts. In addition to bait, a single paper towel was placed in each trap to provide bedding if an animal was captured. Traps were set in the late afternoon, and checked early the next morning. Surveys were conducted only in areas identified as suitable habitat. All captured animals were identified and released at the site of capture. Criteria developed by Shellhammer (1984) were used to differentiate the salt marsh harvest mouse from the western harvest mouse (*Reithrodontomys megalotis*).

2. Data Limitations

The techniques used during SMHM surveys are standard practice for small mammal presence/absence surveys. There have been no long-term studies of SMHM in the marsh, so estimates of population numbers or viability cannot be made. The surveys that captured SMHM only established that mice were present at the time of the survey. Unsuccessful survey efforts cannot be construed to mean that SMHM were not present, since trapping was conducted on a limited basis.

C. Data Results

Although the period covered by this Comprehensive Review is 1985-1995, there were important SMHM surveys conducted after 1995, and the results are included here.

The locations of SMHM surveys in the marsh from 1985-1998 are shown in Figure IX-2, and the results discussed below.

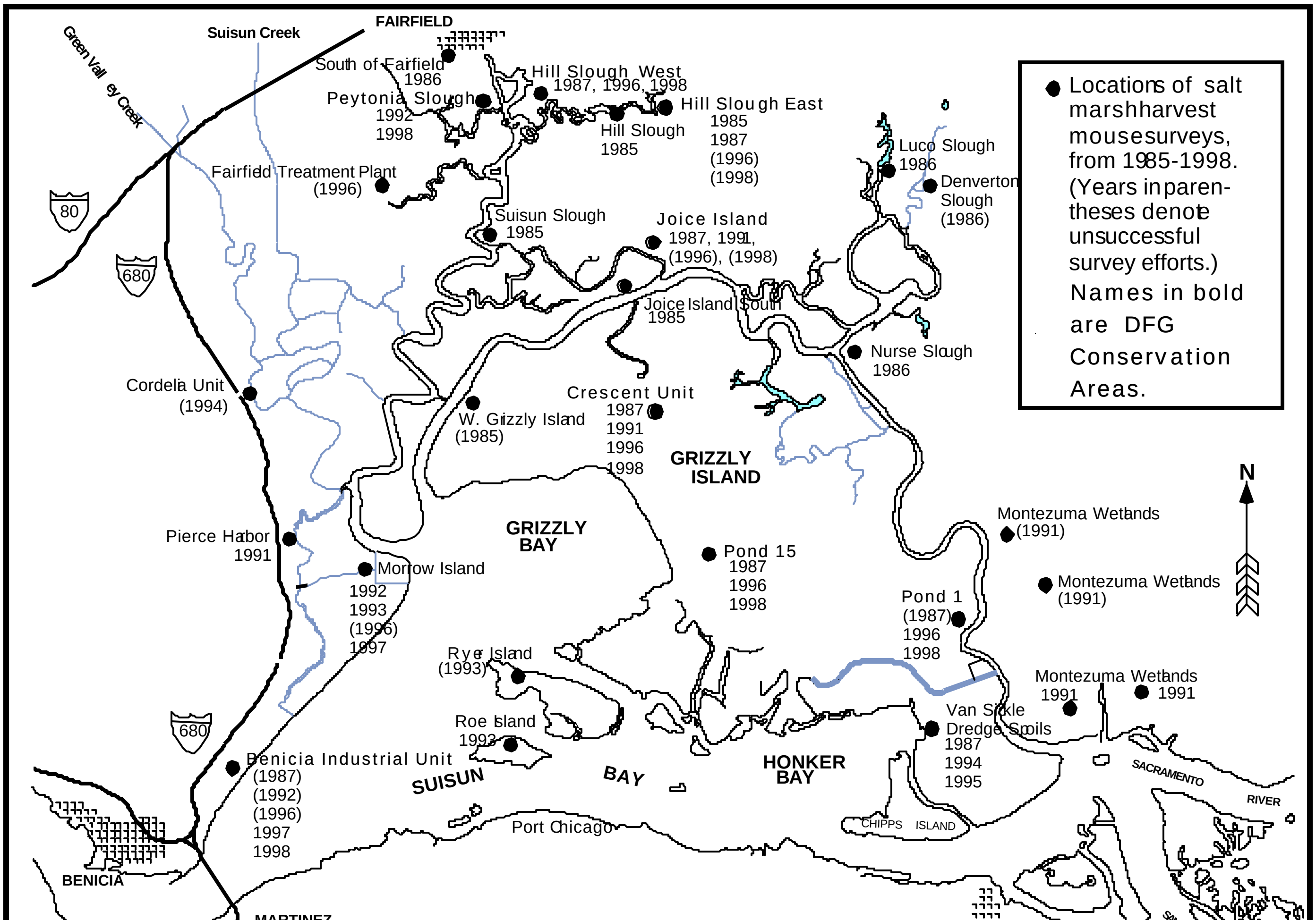


FIGURE IX-2. Locations of salt marsh harvest mouse surveys in Suisun Marsh, 1985-1998.

1. Results of survey efforts at the conservation areas (Table IX-1)
The seven conservation areas were first surveyed by DFG in November and December 1987 (DFG 1988). One hundred traps were set for three consecutive nights at each area, except Hill Slough West where no trapping was done because the area was flooded. No SMHM were captured at either Pond 1 or Benicia Industrial Unit. Vegetation was sparse at Pond 1 because of a fire, and much of Benicia Industrial Unit was flooded.

Table IX-1. Results of surveys on Suisun Marsh conservation areas for the salt marsh harvest mouse, 1985-1999. All data are DFG unpublished data. See Notes at end of chapter for availability of records.

Trapping location	Date	# trapnights	# SMHM + # recaptures	Success (SMHM/trapnights)
Benicia Industrial	Dec-87	300	0	0.000
	Sep-92	50	0	0.000
	Jul-96	49	0	0.000
	Jun-97	492	1	0.002
	Aug-97	798	18 + 3	0.023
	Aug-98	300	28 + 8	0.093
	May-99	120	10 + 1	0.083
Crescent	Dec-87	300	11	0.037
	Mar-91	80	8	0.100
	Jul-96	96	14	0.146
	Aug-98	300	4 + 1	0.013
	1999	220	56 + 11	0.250
Hill Slough East	Dec-87	300	8	0.027
	Jul-96	30	0	0.000
	Aug-98	450	0	0.000
	Aug-99	300	1	0.003
Hill Sl West	Jul-96	49	1	0.020
	Aug-98	300	6 + 2	0.020
Joice Island	Dec-87	300	7	0.023
	Mar-91	80	12	0.150
	Jul-96	20	0	0.000
	Aug-98	450	0	0.000
	1999	500	5	0.010
Peytonia Slough	Jul-92	100	5	0.050
	Sep-92	60	3	0.050
	Sep-98	300	12 + 4	0.040
Pond 1	Nov-87	300	0	0.000
	Jul-96	50	3	0.060
	Sep-98	300	9 + 4	0.030
	1999	400	8 + 4	0.020
Pond 15	Dec-87	300	7	0.023
	Jul-96	30	2	0.067
	Aug-98	300	7 + 2	0.023

In March 1991, Joice Island and Crescent Unit were surveyed.   Forty traps were used at each area and set for two consecutive nights. Traps were placed in the same areas that were surveyed in 1987, and SMHM were captured at both areas.

All seven areas were surveyed in July 1996. Each area was only surveyed for one night and there were variable numbers of traps (20-96) set at each site. SMHM were not captured at Benicia Industrial Unit, Hill Slough East, or Joice Island. Benicia Industrial Unit was partially flooded, and traps could only be placed along the eastern edge near the railroad levee. Scattered seed and missing paper towels indicated that rodents had visited the traps at Hill Slough East, but it was assumed that the trigger mechanism was improperly set since none of the traps were closed. Only 20 traps were placed in one small patch of pickleweed at Joice Island.

More extensive surveys of the conservation areas were done in 1998. One hundred traps were placed at each area and set for three consecutive nights. SMHM were captured at all areas except Joice Island and Hill Slough East. These two areas were surveyed for an additional three nights during low tide, using 50 traps each night, but no SMHM were captured during this effort, either. Lack of success at these areas may have been due to small or sparsely vegetated patches of pickleweed habitat.

During 1999, four existing (Crescent, Pond 1, Joice Island, and Hill Slough East) and seven proposed conservation areas were surveyed, and SMHM were captured at all areas, including the two areas (Joice Island and Hill Slough East) where no SMHM were captured in 1998. Overall, capture rates were substantially higher than in 1998, indicating that the species recovered from the effects of the 1998 flooding.

2. Survey efforts at other areas since 1985

Several other areas of the marsh have been surveyed for SMHM, by DFG or private consultants (Table IX-2). These efforts were often for biological assessments for proposed projects. The location and results of these efforts are listed in Table IX-2.

While trapping in Suisun Marsh for the Suisun shrew, Western Ecological Services Company (WESCO 1986) captured several SMHM in 1985 and 1986. The eight areas surveyed and SMHM captures are listed at the top of Table IX-2.

In 1986, Howard Shellhammer successfully surveyed a diked wetland south of Fairfield.

As part of the biological assessment for the proposed Montezuma Wetlands Project, Levine/Fricke (1995) surveyed several areas near Collinsville in 1991; SMHM were only captured at the southern end of the property.

Table IX-2. Results of SMHM surveys on Suisun Marsh lands other than those designated as conservation areas for the salt marsh harvest mouse, 1985-1999.
***see Notes at end of chapter**
****areas proposed in 1999 as SMHM conservation areas.**

Trapping location	Date	# trapnights	# SMHM (+ recaps)	Success (SMHM/trapnights)	Source
West Grizzly Island	Oct-85	300	0	0.000	WESCO 86.
Hill Slough	Oct-85	300	1	0.003	WESCO 86.
Joice Island, south	Oct-85	300	2	0.007	WESCO 86.
Suisun Slough	Oct-85	300	4	0.013	WESCO 86.
Morrow Island	May-86	300	0	0.000	WESCO 86.
Luco Slough	May-86	375	3	0.008	WESCO 86.
Nurse Slough	May-86	400	7	0.018	WESCO 86.
Denverton Slough	May-86	300	0	0.000	WESCO 86.
S of Fairfield, W of Suisun City	Sep-86	1800	10	0.006	Natural Diversity Data Base
Montezuma Wetlands NW	Jun-91		0		Levine/Fricke 1995
Montezuma Wetlands Central	Jun-91		0		Levine/Fricke 1995
Montezuma Wetlands S	Jun-91		8		Levine/Fricke 1995
Montezuma Wetlands SE	Jun-91		13		Levine/Fricke 1995
Van Sickle Dredge	Mar-87	444	46	0.104	DFG unpub. data*
Van Sickle Dredge	Aug-94	49	4	0.082	DFG unpub. data*
Van Sickle Dredge	Sep-95	49	4	0.082	DFG unpub. data*
Pierce harbor	Jul-91	120	10	0.083	DFG unpub. data*
Fairfield treatment plant	Jun-91	150	0	0.000	DFG unpub. data*
Goodyear Slough Outfall	Sep-92	30	2	0.067	DFG unpub. data*
Morrow Island	Sep-92	99	6	0.061	DFG unpub. data*
Morrow Island	Sep-93	150	1	0.007	DFG unpub. data*
Morrow Island	Jun-97	~4000	28	0.007	DFG unpub. data*
Roe Island	Jul-93	50	3	0.060	DFG unpub. data*
Ryer Island	Jul-93	100	0	0.000	DFG unpub. data*
Cordelia Unit	Jul-94	90	0	0.000	DFG unpub. data*
Hill Slough Central	Jul-96	20	0	0.000	DFG unpub. data*
Hill Slough West Pond 1**	Jun-05	220	27	0.123	DFG unpub. data*
Pond 12F**	Jul-99	170	34 + 11	0.200	DFG unpub. data*
Area 11**	Jul-99	300	49	unknown # recaps	DFG unpub. data*
Hill Slough West Area 4A**	Jun-99	300	15 + 1	0.05	DFG unpub. data*
Area 12**	Jul-99	200	21 + 7	0.105	DFG unpub. data*
Hill Slough East Area 9**	Aug-99	300	23 + 7	0.077	DFG unpub. data*
Goodyear Slough Unit**	Aug-99	284	18 + 11	0.063	DFG unpub. data*

Dredge spoils from the construction of the Suisun Marsh Salinity Control Gates were deposited at a site on Van Sickle Island in 1987. In March 1987, prior to deposition of spoils, SMHM were captured and removed to Hill Slough West. After removal of the spoils, and regrowth of pickleweed, the area was surveyed to determine if SMHM had returned to the area. Survey efforts in 1994 and 1995 were both successful in capturing SMHM. For details of these surveys, see Final Monitoring Report for the Revegetation of Dredge Disposal Site 2 on Van Sickle Island, Bay-Delta and Special Water Projects Division, DFG, January 1998.

In 1991, when DWR and USBR were considering construction of further facilities to improve channel water quality in the marsh, DFG surveyed for SMHM along the alignment of the proposed Boynton-Cordelia Ditch. SMHM were captured near Pierce Harbor, but none were captured near the Fairfield Wastewater Treatment Plant.

Peytonia Slough is a DFG Ecological Reserve that was proposed in 1987 for inclusion in the SMHM conservation areas. The area was designated a SMHM conservation area in 1999, and has been successfully surveyed for SMHM three times since 1985.

The area around two DWR facilities in the western marsh, Goodyear Slough Outfall and Morrow Island Distribution System, have been successfully surveyed for SMHM. The most recent surveys at Morrow Island occurred in 1997 when the Distribution System was dredged. SMHM were trapped in and removed from the area where dredge spoils were deposited. Captured mice were released at the Benicia Industrial Unit conservation area.

In 1993, Roe and Ryer islands in Suisun Bay, which are the property of the Concord Naval Weapons Station, were surveyed for SMHM by DFG. Bad weather ended the trapping after only one night. SMHM were only captured on Roe Island.

In 1994, DFG property in the Cordelia Unit was surveyed for SMHM. The habitat was poor for SMHM and none were captured.

While surveying the conservation areas in 1996, traps were placed on private property along Hill Slough in an area between the two conservation areas. No SMHM were captured.

D. Conclusions

Although regular survey efforts did not begin until 1998, the data collected indicate that SMHM populations are widespread and persistent in the marsh. No population estimates can be made, but SMHM do appear to have viable populations at Crescent Unit, Hill Slough West, Pond 1, Pond 15, Van Sickle Dredge Spoils, Peytonia Slough, and Morrow Island. Results of 1998 surveys indicate that flooding that occurred in February 1998 may have decreased populations at Pond 1 and Crescent Unit, but did not eliminate the species.

No SMHM were captured at two tidal wetlands, Joice Island and Hill Slough East, in 1998. SMHM were captured at both areas in the past and in 1999; lack of success in 1998 (and low success in 1999) may be due to size of pickleweed patches or general condition of the pickleweed. The health and extent of pickleweed may have been adversely affected by low salinity conditions in recent years.

E. Recommendations

The results of the 1998 and 1999 SMHM surveys revealed that there are substantial data gaps on SMHM biology in Suisun Marsh, particularly concerning habitat usage and the genetics of the SMHM and western harvest mouse. The following research suggestions were made by the SMPA ECAT during meetings in 1999.

- Conduct a genetic study to determine genetic markers of SMHM and western harvest mice, and correlate these markers to morphological characteristics.
- Surveys to assess SMHM usage of non-typical habitats.
- Determine the effects of wetland management on the SMHM.
- Intensive surveys to estimate population size.

Notes

DFG Unpublished data. The memos and reports containing these data can be obtained from Patty Finfrock, Department of Water Resources, Environmental Services Office, 3251 S Street, Sacramento, CA 95816.

NDDB is the Natural Diversity Database, a digital product of the California Department of Fish and Game. It is available through their Wildlife and Habitat Data Analysis Branch, 1807 13th Street, Suite 202, Sacramento, CA, 95814

Chapter X
Aquatic Resources

A. Introduction

This chapter covers aquatic resources monitoring specified in the regulatory permits for construction and operation of the Suisun Marsh Salinity Control Gates. To meet the permit requirements, DWR and USBR submitted a monitoring plan in March 1988. In subsequent years, regulatory agency staff have raised additional issues which DFG, DWR, and USBR have attempted to address through additional monitoring and analysis. The following sections describe the permit conditions, monitoring plan, study objectives, methods, results and recommendations for the aquatic resources component of DWR's Suisun Marsh monitoring program.

The results, in general, have not led to definitive findings on SMSCG impacts to aquatic resources. Overall, it is not possible to directly assess the impact of the SMSCG, since the "control" or "background" condition for such an assessment (*i.e.,* no gates) no longer exists. Thus, in general, the data analyses address the question indirectly by comparing data collected prior to gate installation with that collected after gate installation in 1988, or by using the "no gate operation/flashboards removed" configuration as the control.

Through these analyses, impacts to adult salmon migration have been identified and there is a possibility of increased predation on juvenile salmon. Adult salmon approaching the SMSCG have been delayed, and at times their passage has been blocked. DWR, USBR and the SMSCG Steering Group will test the effectiveness of leaving the boat lock open for salmon passage in the fall of 2001 and 2002. Additional studies to determine impacts on juvenile salmon may be warranted since previous studies did not clearly link SMSCG installation and operation with increased predation levels or impacts to juvenile salmon migration.

B. Permit Conditions

Three permits address potential impacts of the SMSCG on aquatic species. The permits are the US Army Corps of Engineers Permit #16223E58, the San Francisco Bay Conservation and Development Commission Permit 4-84M, and the National Marine Fisheries Service 1993 Biological Opinion for Operation of the Federal Central Valley Project and the CA State Water Project.

The ACOE permit required DWR (and USBR) to develop a monitoring program that would address 3 issues:

- the magnitude and nature of delays to migratory fish,
- the magnitude and nature of predation losses to migratory fish, and
- a list of indicator species whose population would be studied.

The permit also required the permittee to develop criteria that would be used to determine whether the SMSCG are causing "significant degradation or excessive predation of the aquatic ecosystem." If the criteria are exceeded, DWR and USBR are required to mitigate for the effects.

The BCDC permit also calls for the development of a monitoring program. The monitoring program would address:

- existing fisheries resources before construction of the SMSCG,
- a continuing study of fishery resources and related aquatic life impacted by the project, and
- a pre- and post-gate evaluation and analysis of effects of the structure and operation on fish migration, species composition, age classes, diversity and abundance and food sources within Montezuma Slough.

The NMFS 1993 Biological Opinion required DWR and USBR to implement several reasonable and prudent alternatives for the long-term operation of the CVP and SWP. The reasonable and prudent measures specified for operation of the SMSCG state that: "The DWR, in coordination with the USBR, must develop and implement a program of chinook salmon investigations at the (SMSCG) and within Montezuma Slough. Chinook salmon investigations must be designed to address..."

- diversion rate of juvenile salmon into Montezuma Slough,
- predation of juvenile salmon at the structure,
- survival of juvenile salmon during passage through Montezuma Slough, and
- passage of upstream migrant adults at the SMSCG.

C. Monitoring Program

To fulfill the ACOE and BCDC permit requirements, DWR (and USBR) submitted a monitoring plan (Spaar 1988) to the agencies. The monitoring plan addressed five topics as they relate to gate operation, namely, *Neomysis*, general fish abundance, chinook salmon smolts, striped bass egg and larvae, and juvenile striped bass. In subsequent years, Department of Fish and Game staff developed studies to determine if predator abundance around the structure had changed and to determine if the structure and/or its operation delays adult salmon migration.

This chapter evaluates the methods, data limitations and results of each of these aquatic resource monitoring studies, and recommends if and how the studies should be continued.

D. *Neomysis* Monitoring

1. Introduction

This section discusses the abundance of *Neomysis mercedis* and concentration of chlorophyll *a*, an indicator of phytoplankton abundance, over time. The *Neomysis* monitoring element addresses the BCDC permit requirement for studying food availability in Montezuma Slough. One of the purposes of studying *N. mercedis* and chlorophyll concentration in the marsh is to determine whether SMSCG operations directly or indirectly impact *N. mercedis* abundance. In previous DWR annual reports to the ACOE and BCDC, this monitoring element has been discussed by examining trends in chlorophyll *a*, and *N. mercedis* concentrations over time. (This section of the report contains information on abundance trends of phytoplankton and *Neomysis* observed in the Delta. Although discussion of this information is not required to fulfill SMSCG permit requirements, it provides a context for understanding processes that may be occurring in the marsh.)

N. mercedis is a euryhaline zooplankton species that has peak abundance in the entrapment zone (Obrebski and others 1992). Although it has broad salinity tolerance, field studies indicate *N. mercedis* abundance decreases at salinity levels above 7.2 ppt (11.3 mS/cm) and is extremely low when salinity exceeds 18 ppt (Heubach 1969). Phytoplankton is the primary food source for *N. mercedis*, which in turn, is an important dietary component for many marsh fishes. Phytoplankton abundance can change quickly, which may affect the abundance of *N. mercedis* and, indirectly, that of many fish species.

The Preproject Fishery Evaluation (Spaar 1988) indicated that *N. mercedis* sampling conducted by DFG should be continued. It further suggested that *N. mercedis* abundance might be linked to hydraulic conditions in Montezuma Slough and the presence or absence of the entrapment zone. Thus, the evaluation stated that a hydrodynamic study would be initiated in Spring 1989. Goals of the hydrodynamic study were to determine how operation of the SMSCG affects velocity and density circulation in Montezuma Slough. Longitudinal transects were to be made through the slough at various tidal and flow conditions before and after the SMSCG were in place. During these transects, vertical profiles of temperature, salinity and turbidity were to be used to detect the presence of an entrapment zone. This hydrodynamic element was also to include a 30-day deployment of meters upstream and downstream of the structure.

For this hydrodynamic study, DWR completed depth profiles at 19 stations in Montezuma Slough on a monthly basis from May 1988 through January 1991. Data on electrical conductivity, water density and depth were collected. However, these data were never analyzed and were subsequently lost.

In 1990 and 1991, DWR conducted field tests in Montezuma Slough to: (1) gather flow, volume, and stage data to evaluate gate efficiency and assist with marsh model verification; (2) evaluate operating options, including ability of control gates to meet standards under various water quality conditions; and (3) gather velocity and flow data to compare with acoustic velocity meter data. While these studies evaluated flow and velocity, they did not investigate the other parameters described for the hydrodynamic study and thus provide no information on the relationship between gate operations, presence of the entrapment zone in Montezuma Slough, and *N. mercedis* abundance. Alternative evaluations are discussed below which address aspects of this question.

2. Methods

Since 1972, the Department of Fish and Game has conducted field sampling for zooplankton and *N. mercedis* in Suisun Marsh. In 1976, Fish and Game began taking chlorophyll *a* samples as well. Historically, three sites (32, 33, 34) were sampled in Montezuma Slough and one in Suisun Slough (S-42) (Figure X-1). *N. mercedis* sampling station 33 was discontinued in 1977, and 34 was discontinued in 1984. (Please note: these stations should not be confused with the DWR Suisun Bay and marsh Compliance Stations which have similar names.) Since 1984, only 32 and S-42 have been sampled. The site on Montezuma Slough is about 15 miles downstream of the Salinity Control Gates, at the western end of the slough. Until 1996, *N. mercedis* and phytoplankton sampling occurred twice monthly from March through October. Normally there was no sampling in November-March due to naturally low winter abundance of *N. mercedis.* However, in water years 1996 and 1997, *N. mercedis* and chlorophyll sampling was conducted monthly throughout the year. In 1998, *N. mercedis* samples were collected each month, although chlorophyll samples were not collected until May of that year.

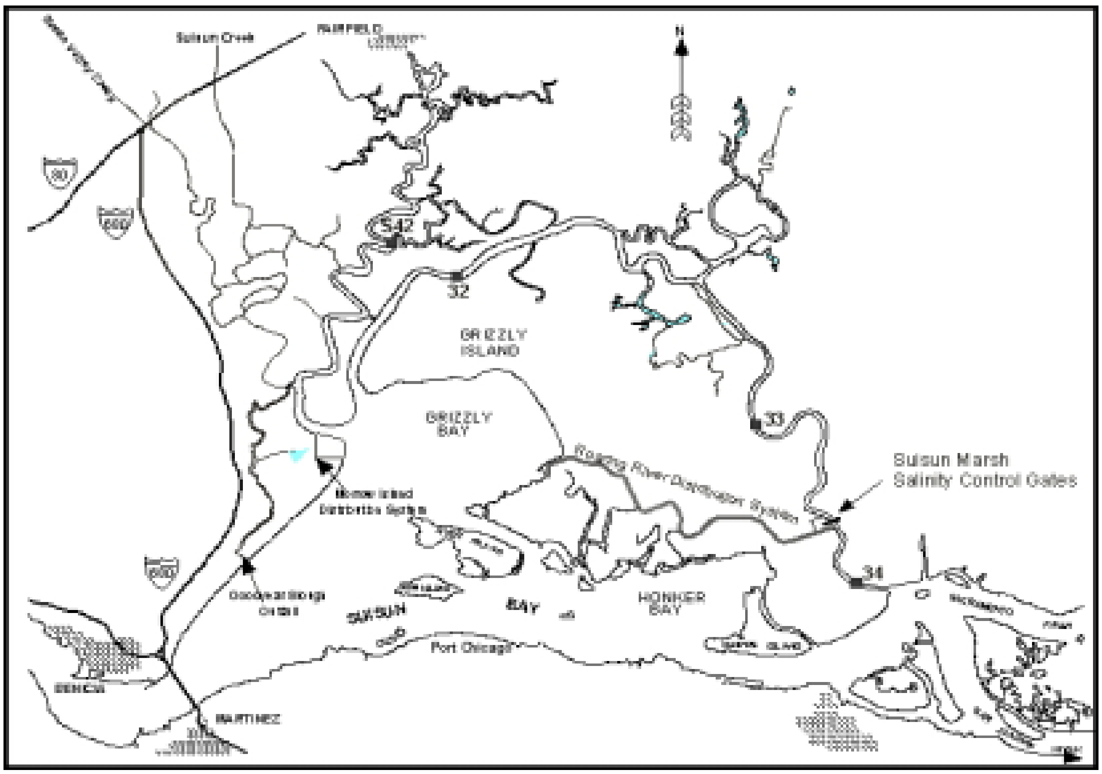


Figure X-1. Current and historic DFG zooplankton and Neomysis sampling stations in Suisun Marsh

At each site, one *N. mercedis* sample, two zooplankton samples, and one chlorophyll *a* sample are taken. Since 1994, numbers of *Acanthomysis bowmani,* an exotic mysid species recently introduced from Asia, have also been enumerated. Surface temperature, water transparency (Secchi depth), and specific conductance are also measured. *N. mercedis, A. bowmani* and larger zooplankton are sampled using a bottom-to-surface oblique tow through the water column with nets attached to a tow frame. Tows last 10 minutes. The *N. mercedis* net used since 1974 has a mesh size of 0.505 mm and mouth diameter of 30 cm and is 1.48 meters long. The zooplankton net, which is mounted above the *N. mercedis* net, is made of No. 10 nylon mesh, has a mouth diameter of 10 cm, and a length of 73 cm. To sample for microzooplankton, a hose is raised from the bottom to the surface of the water column. At the same time, water is pumped through the hose into a carboy. Subsamples are taken from the water in the carboy. Water for chlorophyll *a* samples is taken from a depth of 1 meter.

3. Data Limitations

It is not possible to determine whether SMSCG operations are impacting *N. mercedis* abundance in the marsh due to the lack of a control treatment. Instead, long-term abundance data from the marsh are examined and compared to trends of *N. mercedis* abundance in the Delta. Further, changes in phytoplankton standing crop, as indicated by chlorophyll *a* concentration, are also discussed, because they may impact observed *N. mercedis* abundance.

4. Results

a. Chlorophyll* a *Concentration

Overall, chlorophyll *a* concentration has decreased in Suisun Marsh since 1987 (Figures X-2 and X-3). During drought years, this decline has been attributed partly to decreases in freshwater flows (Monroe and others 1992). However, the primary factor affecting chlorophyll *a* concentration in recent years in the San Francisco Estuary has been the presence of the suspension-feeding clam *Potamocorbula amurensis*, which invaded this area in 1986 and has since become abundant (Alpine and Cloern 1992; Herbold and others 1992). Alpine and Cloern determined that mean estimated primary production between 1977 and 1990 decreased from 106 to 39 g C $m^{-2}yr^{-1}$ in the deep channels and adjacent shallows of the San Francisco Estuary, presumably due to the intensive grazing pressure by the clam in this region.

The University of California, Davis, Suisun Marsh fisheries monitoring reports indicate that *P. amurensis* is present in many locations in Suisun Marsh (Matern and others 1995). The clam is reported to be abundant near the downstream mouth of Suisun Slough and has invaded the upstream regions of the slough. In 1994, *P. amurensis* was collected near the Suisun Marsh Salinity Control Gates. In 1996 it was collected at only three western sites in the marsh, while it was collected at five sites in 1997: all four stations on Suisun Slough and one upstream station on Goodyear Slough (Matern and others 1997). In 1998 clams were present in lower Suisun Slough, although relatively few were collected and many of those collected were dead (Matern and others 1999). High mortality can result when salinity is low for a prolonged period of time (Peterson 1997).

The decrease in chlorophyll *a* concentrations has been apparent in the marsh since 1987, when the clam became abundant and widespread in the bay and estuary. Between 1976 and 1987, 25% of all phytoplankton samples collected in the marsh by DFG were at least 20 µg/L, and 43% were less than 10 µg/L. Between 1988 and 1998, 2% of all samples were greater than or equal to 20 µg/L, and 92% of the samples were less than 10 µg/L. The decline appears to have accelerated in recent years; since 1992, 98% of all samples (138 out of 141 samples) were $\leq$5 µg /L. This 11-year decline in chlorophyll *a* appears most tightly linked to the invasion of *P. amurensis* (Monroe and others 1992). Herbold and others (1992) suggest that even with an increase in freshwater flows, phytoplankton productivity may continue to be depressed, since *P. amurensis* can tolerate a wide range of salinity.

Construction and operation of the Suisun Marsh Salinity Control Gates do not appear to have further decreased chlorophyll *a* levels. In water year 1989, the year after gate operations began, chlorophyll *a* was higher than in those years immediately preceding gate installation. For example, chlorophyll *a* values in water year 1988 were 1.3-15.9 µg /L; in 1989 they were 1.3-36.1 µg /L. The peak in 1988 was in April through July, with values of 3.7-15.9 µg /L in Suisun and Montezuma sloughs. In 1989, the peak was later, June-October, and values in the two sloughs were 4.1-36.1 µg/L (above 15 µg/L during 5 of those months). Whether the concentration of chlorophyll or timing of the bloom in 1989 resulted from conditions brought about by control gate operations would be difficult to determine. However, these data do suggest that the first year of operation did not decrease phytoplankton production. Further, in 1990-1991, chlorophyll *a* concentration ranged from 0.8-15.7 µg/L, making it comparable to concentrations in 1987-1988 (0.3-20.4 µg/L) prior to gate operation.

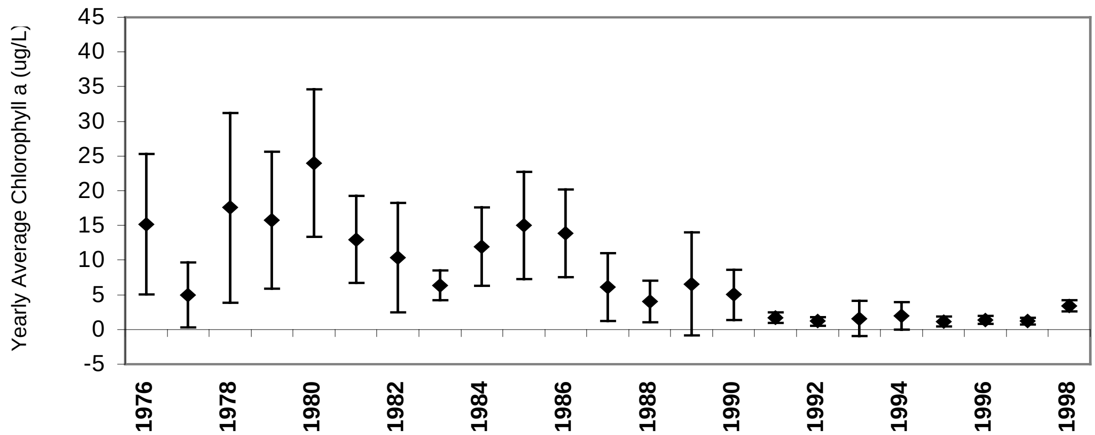


Figure X-2. Yearly average chlorophyll *a* and standard deviation values for Suisun Marsh, 1976-1998 at Station 32 on Montezuma Slough

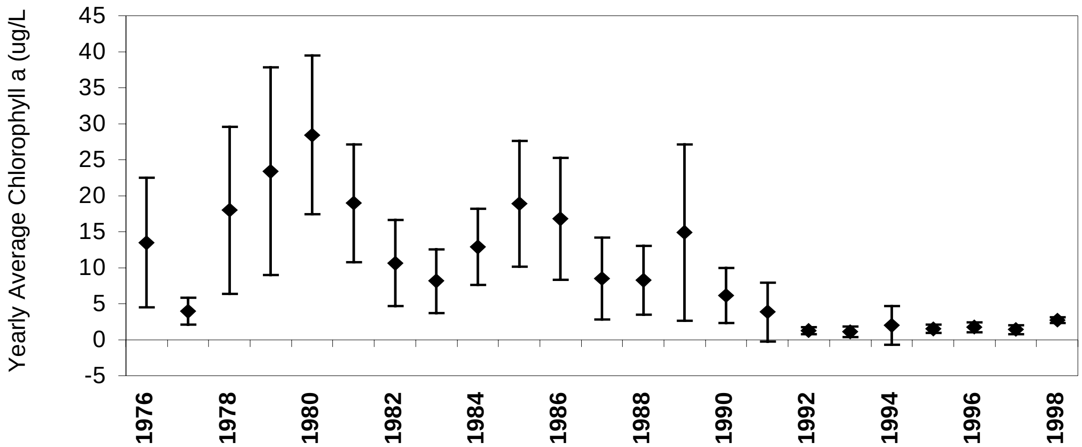


Figure X-3. Yearly average chlorophyll *a* and standard deviation values for Suisun Marsh, 1976-1998, at Station S42 on Suisun Slough

Since approximately 1992, there has been a decrease in yearly average chlorophyll *a* concentration and variability within years (indicated by the standard deviation lines in Figures X-2 and X-3). This suggests that phytoplankton blooms are either not occurring or are not reaching the peak concentrations once measured in the marsh, perhaps due to the grazing by *P. amurensis*. There was no phytoplankton bloom in Montezuma Slough in 1992, a critical water year; chlorophyll *a* concentration was less than 2.4 µg/L on all sampling occasions. Concentrations increased somewhat in 1993, peaking at 10 µg/L in May. In 1994 and 1995, chlorophyll concentrations again were low on all sampling occasions. (No samples were taken in January-April 1995.) In 1994, concentrations were 0.3-6.8 µg/L. In water year 1995, the highest and lowest chlorophyll *a* concentrations were both measured in December; chlorophyll *a* in Montezuma Slough was 5.2 µg/L and in Suisun Slough it was below the limit of detection. In 1996 and 1997, chlorophyll *a* ranged from 0.5 to approximately 2.6 µg/L. Chlorophyll concentrations increased somewhat in 1998; concentrations at the two stations ranged from 2.3 to 4.3 µg/L from May through September. No samples were taken at either station from January through April.

b. **Neomysis mercedis *Abundance***

N. mercedis has been declining in Suisun Marsh since the 1970s, with the most dramatic decreases evident after 1991 (Figures X-4 and X-5). This decline is evident despite fluctuations within years and a dramatic peak in abundance in June 1996, when >3570 ind/m^3 were observed at Station 32. Since approximately 1991, the yearly average abundance of *N. mercedis* has decreased, and the variability within years has also generally decreased (indicated by the standard deviation lines). Between 1972-1976, yearly peaks in abundance were generally between 300-900 ind/m^3, but on occasion were >4000 ind/m^3. In 1977, a drought year, abundance decreased dramatically to <17 ind/m^3. Between 1978-1988, yearly peak abundance of *N. mercedis* was >400 ind/m^3 in 7 of 11 years in Montezuma Slough and 9 of 11 years in Suisun Slough.

Since the start of SMSCG operations in November 1988, yearly peak *N. mercedis* abundance has ranged from <1 to >3570 ind/m^3. In 1991, *N. mercedis* reached levels of 350 ind/m^3 in Montezuma Slough and 680 ind/m^3 in Suisun Slough, which was relatively high compared to abundance in the Delta at that time (Spaar 1992). Like chlorophyll *a*, *N. mercedis* decreased significantly in 1992, a critically dry year; peak abundance was <16 ind/m^3, making it comparable to abundance during the 1977 drought (<17 ind/m^3). From 1992-1995, *N. mercedis* abundance was <60 ind/m^3 on all sampling dates. In 1993, *N. mercedis* abundance increased slightly from 1992 levels, peaking at 57 ind/m^3. Yearly peak abundance was low again in 1994, with <4 ind/m^3. In 1995, abundance was below 1.5 ind/m^3 on all occasions, except twice in Suisun Slough (4 ind/m^3 in April and 7 ind/m^3 in May).

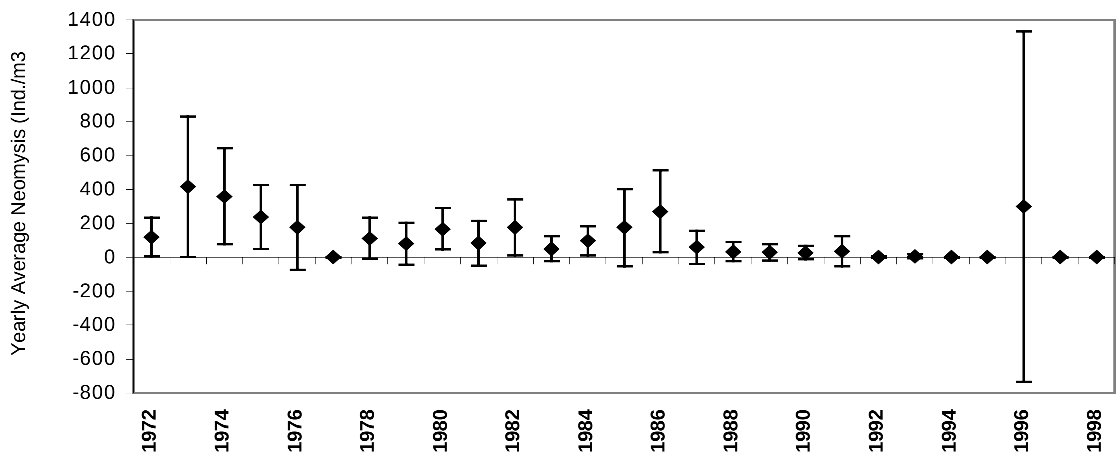


Figure X-4. Yearly average *Neomysis mercedis* density and standard deviation values in Suisun Marsh, 1972-1998, at Station 32 on Montezuma Slough.

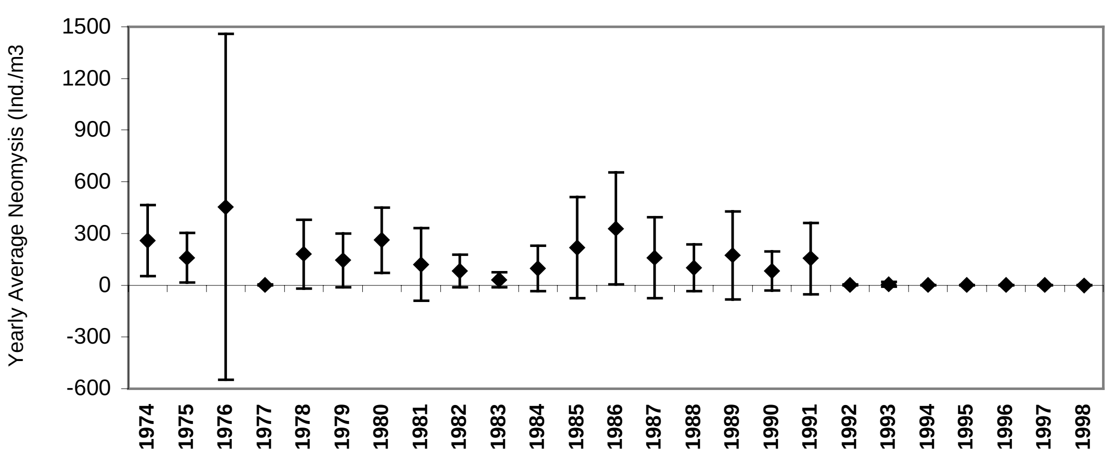


Figure X-5. Yearly average *Neomysis mercedis* density and standard deviation values for Suisun Marsh, 1974-1998, at Station S42 on Montezuma Slough

In water year 1996, *N. mercedis* abundance was less than 6 ind/m^3 until June 1996, when >3570 ind/m^3 were counted at Station 32. This is the highest value on record since June 1976 when 4117 ind/m^3 were observed at Station S42. The population crashed the following month and no *N. mercedis* were observed in the water column during sampling until September 1996, when <1 ind/m^3 was observed. It is not known what factors caused this dramatic population increase in June. Historically, *N. mercedis* peaked twice during the year, once in May-June and again in the fall; however, *N. mercedis* now appear to peak only once during the year, in June (Mecum 1997 personal communication; see "Notes"). Incidentally, this peak in abundance coincided with a dramatic peak in the abundance of *A. bowmani*, the recently introduced mysid species, which reached 11,544 ind/m^3 at Station 32 in June (Figure X-6). (Abundance of *A. bowmani* was less than 37 ind/m^3 on all other sampling dates during the 1996 water year.)

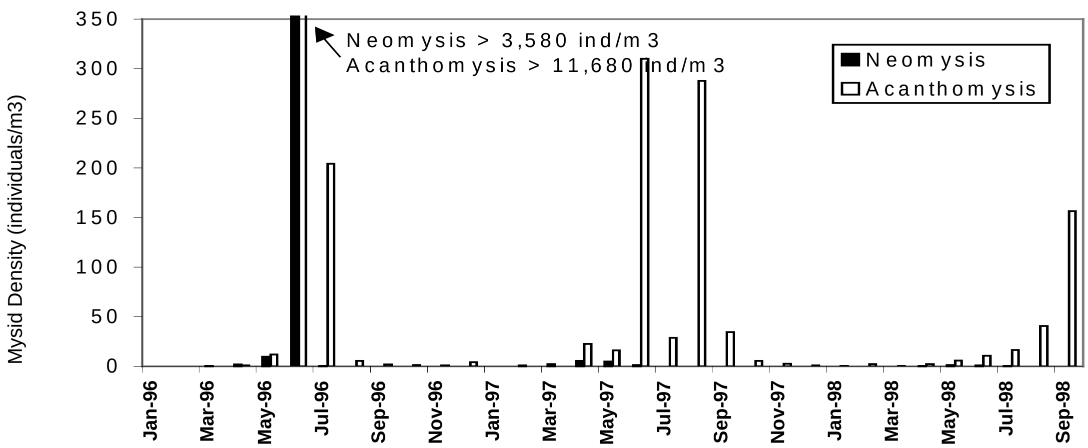


Figure X-6: Combined density of *Neomysis* at Stations 32 and S42 and combined density of *Acanthomysis* at Stations 32 and S42 on a monthly basis in Suisun Marsh, 1996 -1998

Densities of *N. mercedis* were low throughout 1997 and 1998. In 1997 *N. mercedis* densities peaked at 4 ind/m^3 in May. In 1998, N. mercedis was present at Station S-42 from February through August. However, densities were less than 1 ind/m^3 on all sampling occasions, with the maximum concentration occurring in May. At Station 32, *N. mercedis* concentrations were only seen from April through July, and densities were below 1 ind/m^3 on all occasions. Peak density also occurred in May.

The overall decline in *N. mercedis* abundance is consistent with Obrebski and others (1992), who report a decline in the abundance of *N. mercedis* and 12 zooplankton species throughout the Delta in all seasons in 1972-1988. They assert that the declines in zooplankton species are not limited to particular regions of the estuary. In Suisun Marsh, the decline is most apparent after 1991 (Mecum 1995 personal communication; see "Notes"). Food limitation, caused by reduced phytoplankton abundance, is the most probable cause for the decline. Orsi and Mecum's (1994) finding of a significant correlation between *N. mercedis* abundance and chlorophyll *a* concentration in all seasons during 1968-1993 supports this conclusion.

Another factor affecting *N. mercedis* abundance is competition with the recently introduced mysid shrimp, *A. bowmani* (Orsi and Mecum 1994). Orsi (1997) reports that although the introduced mysid was rare during 1992 and 1993, it has been more abundant than *N. mercedis* in the San Francisco Estuary since 1994. Indeed, in 1996 *A. bowmani* densities in the marsh reached 11, 544 ind/m^3 in June. In 1997, *A. bowmani* peaked during the summer 1997, reaching 286 ind/m^3 in August, and in 1998 a peak of 101 ind/m^3 was observed in September (See Figure X-6). Although *A. bowmani* densities during other (non-peak) times of the year vary greatly (e.g. <1 – 37 ind/m^3 in 1996; 0 – 204 ind/m^3 in 1997; and 0 – 55 ind/m^3 in 1998), they are generally much higher than densities of *N. mercedis*. No studies have yet examined the diet of *A. bowmani*, however it is thought to be similar to that of *N. mercedis*. With both species present in Suisun Marsh and the estuarine mixing zone, competition between the species for phytoplankton and zooplankton resources is likely intense (Orsi 1997). Orsi (1997) notes that the decline in *N. mercedis* in 1994, the first year that *A. bowmani* was abundant, suggests that this mysid is out-competing the native *N. mercedis*.

The combined impacts of dry/critical water years, low phytoplankton productivity and invasive species, such as *A. bowmani*, have likely led to the low zooplankton abundance in Suisun Marsh. It is possible that control gate operation during the dry or critical years of 1989 through 1991 helped maintain *N. mercedis* density in the marsh. SMSCG operations may have delayed the impact of the drought on *N. mercedis* density until 1992 by reducing April and May salinity and helping to create more favorable conditions for *N. mercedis*. The 1995 Water Quality Control Plan salinity objectives for the marsh (11.0 mS/cm April-May) are slightly high for optimum *N. mercedis* abundance, but gate operations often keep salinity well below these spring levels. Further, operation of the control gates can produce a saltwater/freshwater interface in the marsh, similar to the larger channels and bays of the estuary, providing suitable salinity for *N. mercedis*. However, without corresponding increases in chlorophyll *a* and/or decreases in the abundance of *A. bowmani*, *N. mercedis* will be unable to benefit from this habitat.

b. Relationship between Hydrology and **Neomysis** *Abundance*

The Preproject Fishery Resource Evaluation (Spaar 1988) discusses the relationship between the entrapment zone and *N. mercedis* abundance during the summer months. Arthur and Ball (1978) postulated that *N. mercedis* density tended to be high in the entrapment zone during the summer months because of the presence of phytoplankton upon which *N. mercedis* feed. As discussed above, the Preproject Fishery Resource Evaluation indicated that studies should be conducted to determine whether SMSCG operations would indirectly impact *N. mercedis* by affecting the position of the entrapment zone in Montezuma Slough. However, since recognition of the relationship between the 2 ppt isohaline line (X_2) and abundance and distribution of various aquatic organisms (Kimmerer and others 1991), the hypothesis regarding *N. mercedis* abundance and the entrapment zone has been seriously questioned.

While the analysis of the impact of the SMSCG on the position of the entrapment zone was never conducted, there is reason to believe that the impact of the SMSCG on *N. mercedis* abundance has been insignificant in the marsh. As discussed above, the invasion and subsequent establishment of *P. amurensis* in the San Francisco Estuary and

Suisun Marsh has profoundly impacted the abundance of phytoplankton. Thompson (1998) asserts that the presence of *P. amurensis* has resulted in a shift in the San Francisco Estuary from a pelagic to a benthic food web. This shift in food web dynamics has resulted in a rapid decline in *N. mercedis* abundance in the Suisun Marsh and San Francisco Estuary in general. Indeed, as mentioned above, changes have been identified in the relationship between the position of X_2, the 2 ppt bottom salinity position, and mysid abundance. Initial analysis by Jassby and others (1995) of mysid data collected between 1972-1982 and 1984-1990 in the Delta and Suisun Bay indicated a statistically significant relationship between the position of X_2 and mysid abundance in the San Francisco Estuary. However, recent analysis indicates that there has been essentially no relationship between X_2 and mysid abundance in the estuary since 1987 (Monismith 1998). Researchers suggest that this may reflect changes in the trophic dynamics due to the establishment of *P. amurensis* and the corresponding decreases in phytoplankton blooms. It is likely that any potential impacts to *N. mercedi*s due to gate operations would be overshadowed by the dramatic impact of *P. amurensis* on the aquatic food web.

5. Conclusions

The overall decline in *N. mercedis* abundance in Suisun Marsh is consistent with the decline observed throughout the estuary, which began in 1972. Reasons for the decline include the impact of drought years, decreases in chlorophyll concentration, changes in food web dynamics due to the establishment of *P. amurensis*, and competition with introduced mysid species such as *A. bowmani*. It is unlikely that SMSCG operations contributed substantially to this decline in the marsh.

6. Recommendations

DWR, with the concurrence of the ACOE and BCDC, proposes to eliminate reporting on this element as a condition of permit compliance since SMSCG operations have not contributed to the decline of *N. mercedis* in Suisun Marsh.

E. General Fish Abundance

1. Introduction

Spaar (1988) described existing fisheries resources before construction of the SMSCG and briefly outlined a continuing study of fishery resources and related aquatic life that may be impacted by the project to meet BCDC permit requirements. Subsequent annual reports (DWR 1992 – 1999) have included a pre- and post-gate trend evaluation and an indirect analysis of effects of the structure and operation on species composition, age classes, diversity and abundance within Suisun Marsh.

The monitoring plan specifically stated two considerations in regard to assessing gate impacts on general fish abundance. The first was that DWR would continue to fund UCD adult and juvenile fishery studies in the marsh for at least three years after initial operation of the SMSCG. DWR has funded the UCD Suisun Marsh adult and juvenile sampling effort from 1979 to the present (11 years after gates began operating). Spaar (1988) also indicated that two Montezuma Slough stations, one upstream and one downstream of the structure, be maintained as part of the UCD sampling effort.

Historical data records and conversations with UCD researchers indicate that monitoring stations at the SMSCG were always downstream of the structure. A station upstream of the SMSCG was never implemented.

Since 1994, DWR has contracted with UCD to conduct a larval fish survey in Suisun Marsh. We have included in this report information gathered in the larval fish survey even though the study was not part of the original Suisun Marsh fish sampling program. The three goals of the larval fish study are:

- To augment the understanding of the marsh fish communities with information on larval stage;
- To determine the extent to which the relatively undisturbed marsh habitats are used by fish for spawning and rearing; and
- To determine if special-status species such as delta smelt, longfin smelt, and splittail are using the marsh for spawning and rearing.

We believe that information from the larval fish study augments the fishery information collected in the program by providing a more complete picture of fishery health in Suisun Marsh.

2. Adult and Juvenile Survey Methods

Monthly samples were taken year-round with a four-seam otter trawl with a 1 x 2.5-meter opening, a length of 5.3 meters, and mesh sizes of 35 mm stretch in the body of the trawl and 6 mm stretch in the cod end. Biologists towed the trawl at about 4 km/hr for 5 minutes in the small sloughs (7-10 meters wide and 1-2 meters deep) and for 10 minutes in large sloughs (100-150 meters wide and 2-4 meters deep). Seining was done with a beach seine 10 meters long with a mesh size of 6 mm.

UCD researchers have trawled at 17 stations throughout Suisun Marsh and seined in Suisun Slough since 1980 (Figure X-7). Fifteen of the stations were in the western marsh and two were in the eastern marsh, both downstream of the salinity control gates. To provide more representative sampling of marsh species, in March 1994 researchers added two otter trawling sites in Nurse Slough and two otter trawling sites and one seining site in Denverton Slough.

At all sites, captured fish were counted, up to 30 individuals of each species were measured to the nearest millimeter standard length, and all fish were returned to the slough. Fish captured in the net range from 12 to 600 mm standard length.

Researchers also recorded actual numbers of shrimp, *Crangon franciscorum* and *Palaemon macrodactylus*, and estimated the abundance of *Neomysis mercedis*. Channel water salinity, temperature, and secchi disk depth were recorded at each site. Tidal conditions were estimated using a *Tidelog*.

3. Larval Fish Survey Methods

The study period has varied somewhat since 1994. Sampling is conducted weekly and generally occurs from February through early June (Table X-1). In 1994, tows were 10 minutes except for 5-minute tows in First Mallard Branch. Since 1995, biologists reduced all tows to 5 minutes because of large samples sizes in 1994. A flow meter attached to the sled measured the volume of water that passed through the net. Water temperature, salinity, and secchi disk depth were measured at each site.

The net used for sampling is mounted on a sled. It is made of 505-micron mesh, and measures 0.362 square meters at the mouth and 3 meters in length. Researchers made three replicate tows in the middle of the channel just under the water surface in Suisun, First Mallard Branch, Nurse, Denverton, and Cordelia sloughs (Figure X- 7).

Table X-1. Dates of UCD larval fish sampling

Year	First sampling date	Last sampling date
1994	15-Apr	17-Jun
1995	26-Feb	15-Jun
1996	2-Feb	11-Jun
1997	2-Feb	5-Jun
1998	28-Feb	11-Jun

The researchers preserved all samples in 10% formaldehyde tinted with rose bengal. All fish were counted unless a sample contained more than 1000 individuals, in which case the researchers estimated the number to the nearest 100. When more than 400 fish were captured in a replicate, researchers randomly subsampled up to 200 fish per jar and identified the fish to the family level. In samples with more than 400 fish, number of fish within each species-family category was adjusted for extra fish in the sample by the following formula:

$$\frac{\text{(total fish identified + extra fish)}}{\text{total fish identified}} \quad \text{x} \quad \text{number of fish identified in each species-family category.}$$

If historical results from the otter trawling indicated that only one species from a family occurred in the marsh, then all individuals captured in that family were assumed to be the known species. However, smelt were identified to the species level and splittail were identified within the cyprinids with identifications confirmed by an independent contractor.

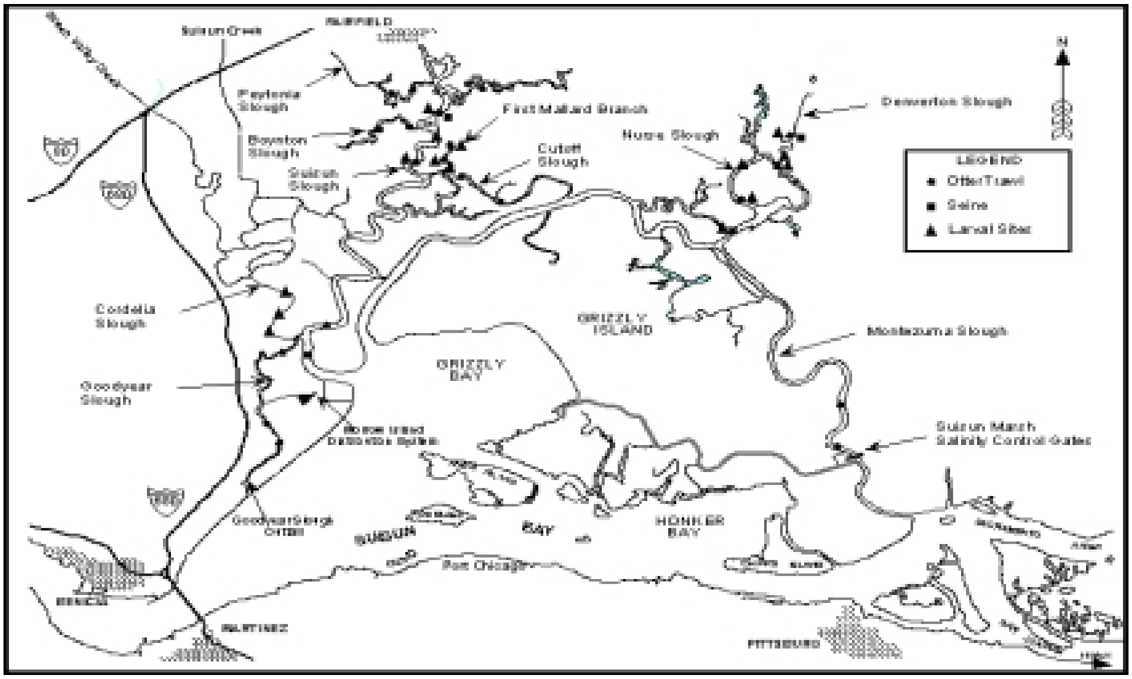


Figure X-7. UC Davis fish sampling sites in Suisun Marsh

4. Data Limitations

As mentioned in the introduction, it has not been possible to directly assess the impact of SMSCG on species composition, diversity and abundance and general fishery resources. All analyses attempted to address the question indirectly by comparing data collected prior to gate installation with that collected after the gates were installed in 1988 (DWR 1995c, 1997a, 1997b, 1999a, 1999b). The data are also limited by gear selectivity for certain size fish, swimming ability, or habitat preference, for example.

5. Results

(Much of the following information can be found in Matern and others 1999.)

The mean catch per trawl of fishes captured in Suisun Marsh declined from 1979 – 1986 and fluctuated at lower levels from 1986 to the present (Figure X-8). Figure X-9 shows that while abundance of native species appears to have declined since the early 1980s, the abundance of introduced species has fluctuated at higher levels. The higher levels of introduced species are largely driven by striped bass abundance.

Figure X-10 compares native species and introduced species abundance over time when striped bass numbers are removed. Native species catch per trawl was higher than introduced species abundance (without striped bass) in 12 of 19 years. Yellowfin goby and shimofuri goby abundances accounted for the higher introduced species abundance in the remaining 7 years.

Diversity appears to have declined since the early 1980s also (Figure X-11). Species captured per trawl was at its lowest level during the early 90’s and in recent years returned to levels seen in the mid to late 1980s.

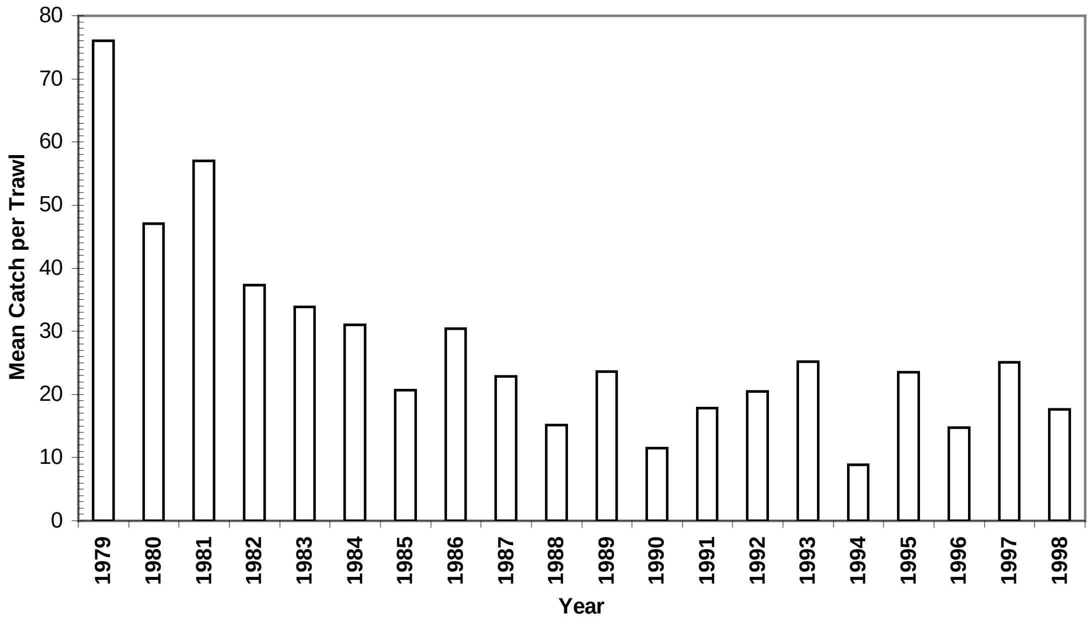


Figure X-8. Mean catch per trawl of fishes captured in Suisun Marsh, 1979-1998 (Matern and others 1999)

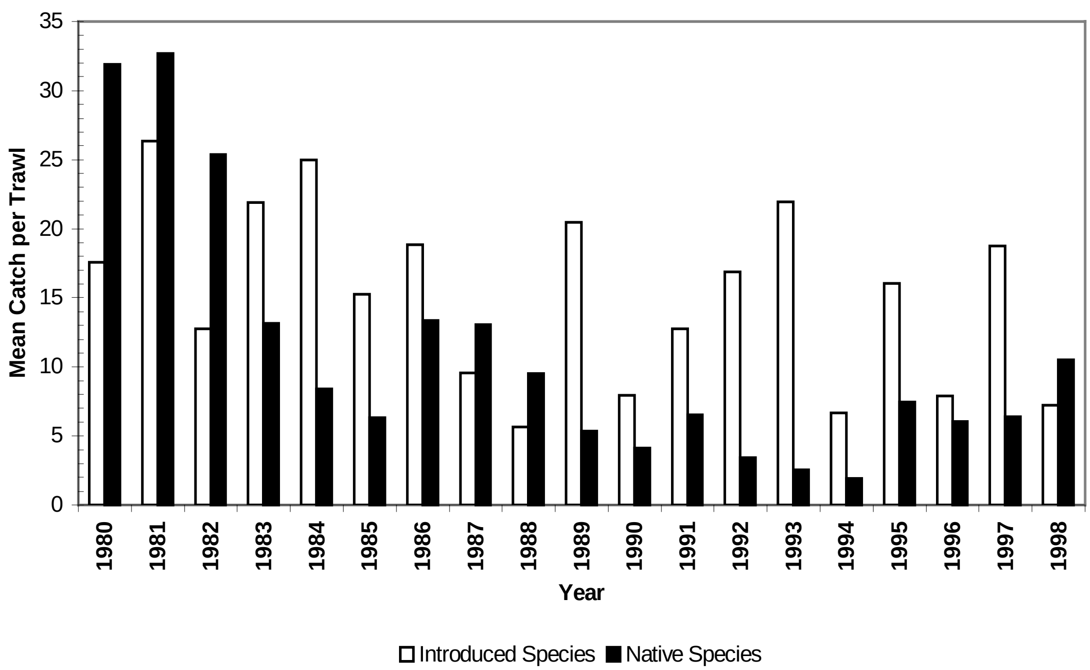


Figure X-9. Mean catch per trawl of introduced and native fishes in Suisun Marsh from 1980-1998

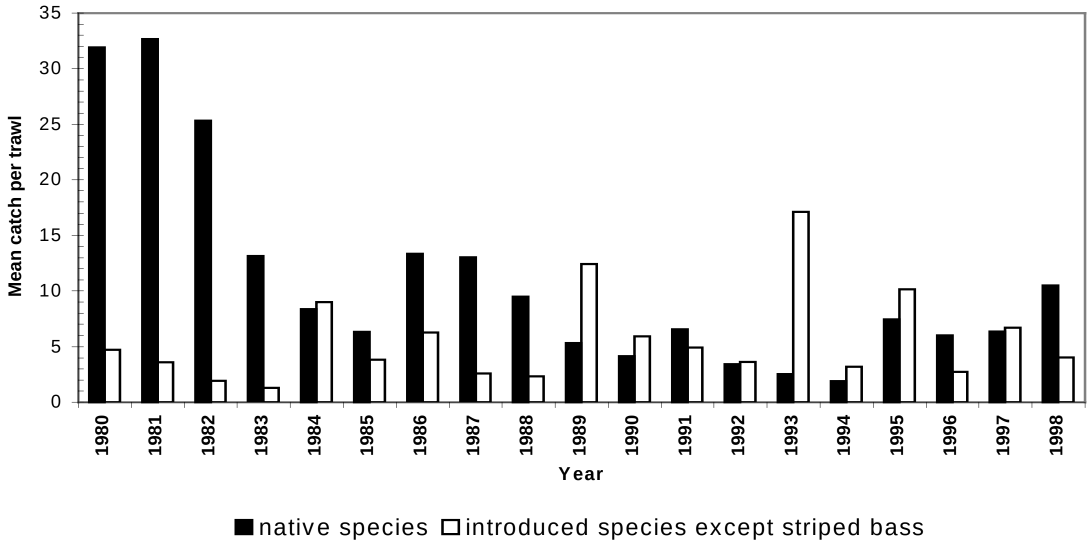


Figure X-10. Mean catch per trawl, native species versus introduced species except striped bass, 1980-1998

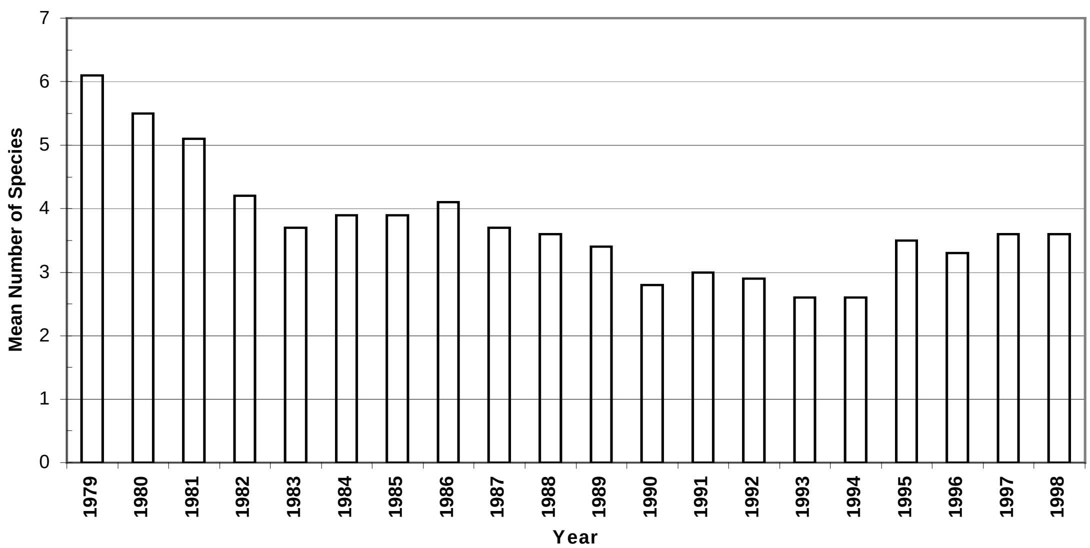


Figure X-11. Mean number of species captured per trawl in Suisun Marsh, 1979-1998

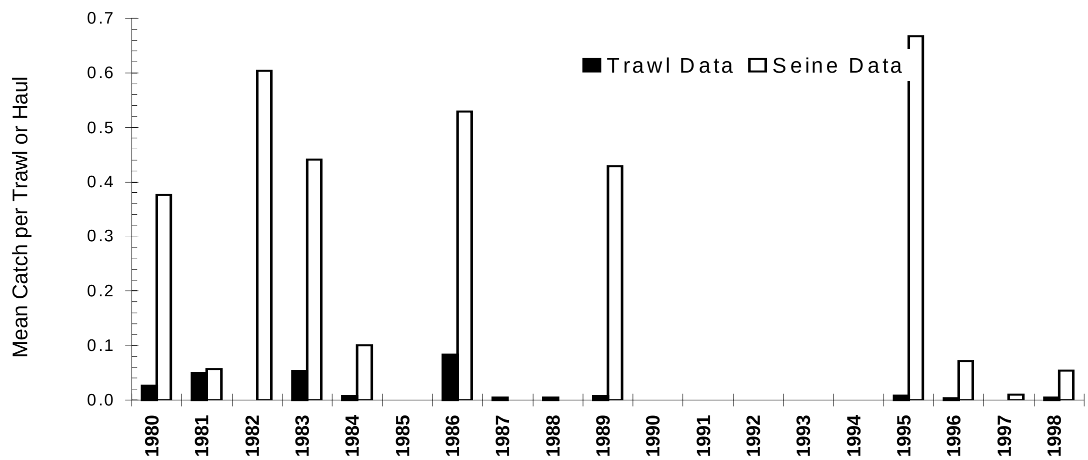


Figure X-12. Catch per unit effort of chinook salmon, 1980-1998

a. Chinook Salmon. In all but 2 years of 1980-1989, biologists captured chinook salmon by trawling (Figure X-12). From 1990-1994, they did not capture any chinook salmon, although some were collected in trawls and beach seines from 1995 through 1998[1]. Since 1980, annual mean abundance of chinook salmon has ranged from 0 to 0.08 fish per trawl. Chinook salmon captured in the trawl have ranged in size from 30 to 370 mm fork length. The beach seine data and the trawl data show that chinook salmon annual mean abundance has fluctuated. Researchers captured 77% of all chinook salmon reported by the study in beach seines. The size of salmon captured in the beach seines has ranged from 30 to 101 mm fork length. All the salmon were captured in January-April and were classified as fall-run based on the Department of Fish and Game daily size criteria.

Pickard and others (1982) reported catching salmon 31-76 mm forklength during sampling in Montezuma Slough at Roaring River in November 1981. These salmon fall in the spring and winter-run size classes.

b. Delta Smelt. Data collected in the larval fish survey indicate that delta smelt use the marsh for spawning and rearing. Researchers generally captured delta smelt in all sloughs sampled (Figure X-13). Highest average densities occurred in Nurse Slough (Figure X-13). From 1994-1998, average abundance of delta smelt peaked in May (Figure X-14 & Table X-2).

[1] Otter trawling may not be particularly effective at capturing salmon since the net is at the bottom of the water column and sampling is done during daylight hours. However, at some Marsh sites the otter trawl samples the entire water column because of smaller slough size. Beach seining may be more effective at capturing young salmonids than the otter trawl. The USFWS has found beach seining effective at capturing fry and smolts in their Sacramento-San Joaquin Delta sampling study (Pierce 2001, personal communication, see “Notes”).

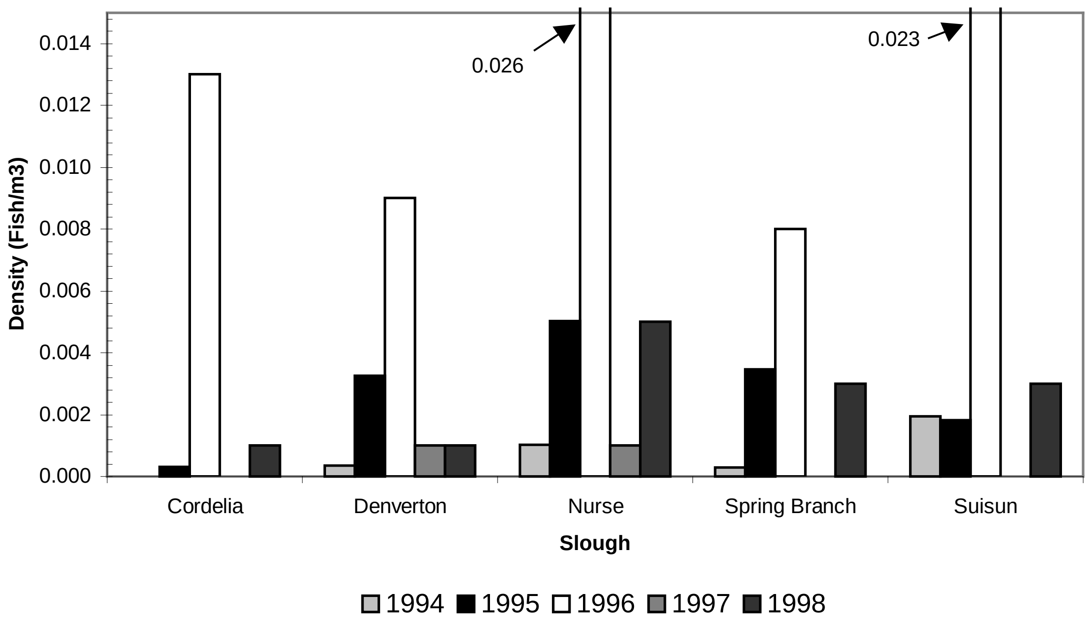


Figure X-13. Average densities of larval delta smelt by slough, 1994-1998

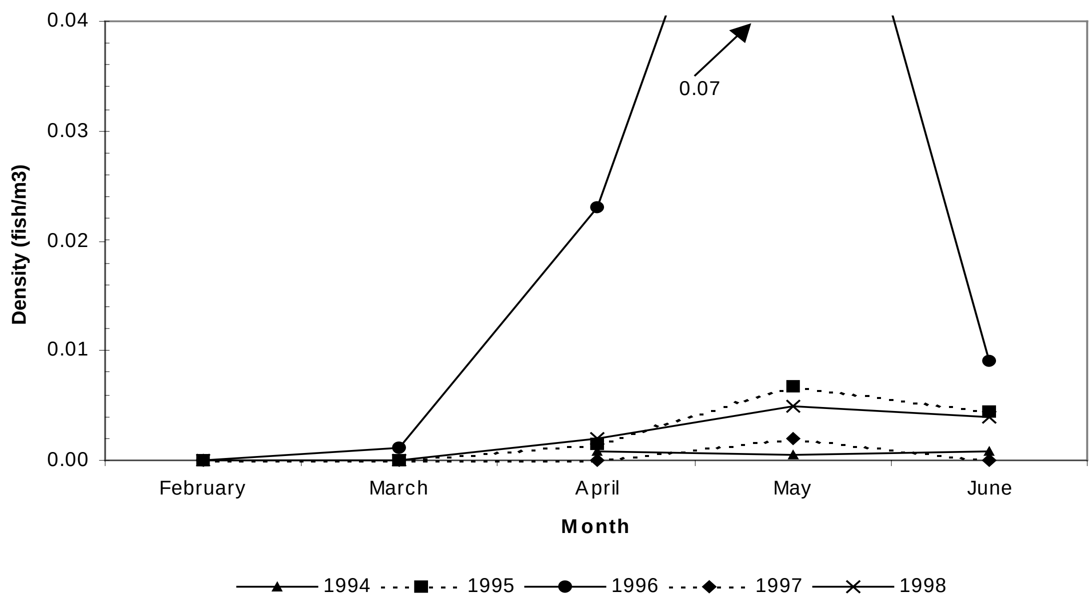


Figure X-14. Average densities of larval delta smelt in Suisun Marsh, 1994-1998

Table X-2. Range of densities of larval delta smelt in Suisun Marsh, 1994-1998

	Month	February	March	April	May	June
1994	Minimum (fish/m3)			0	0	0
	Maximum (fish/m3)			0.009	0.011	0.034
1995	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0	0.025	0.042	0.044
1996	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0.015	0.204	0.528	0.033
1997	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0	0	0.072	0
1998	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0	0.009	0.053	0.044

In general, the annual mean catch per trawl[2] of delta smelt has averaged 0.07 since 1980 and ranged over the whole period from 0 to 0.60 (Figure X-15). Annual mean catch per trawl peaked at 0.60 in the early ‘80s. In 1984-1998, it was 0.05 or less, except in 1994 when it measured 0.07. Of the 474 delta smelt captured since 1980, only 51 were captured since 1983.

The number of delta smelt captured in seines has also fluctuated. Annual mean catch per haul averaged 0.09 since 1980 and ranged from 0 to 0.24. The highest annual mean catch per haul occurred in 1995.

Splittail. Data collected in the larval fish survey indicate that splittail can use the marsh for spawning and/or rearing but it is not a yearly occurrence. Abundance of larvae was highest in 1995 with lower numbers captured in 1996 and 1998. In the years that splittail larvae did occur in the marsh, peak abundance occurred in March, April or May and in Denverton, Spring Branch, and Nurse Sloughs (Figures X-16, X-17, Table X-3).

Catches of splittail in 1998 were lower than in some years in the 1980s (Figure X-18). High numbers were caught in 1980-1983 (annual mean catch of 2.48-7.92 per trawl) and in 1986 (4.41 per trawl). In other years, annual mean catch per trawl ranged from 0.22 to 2.18. The 1995 mean catch of 1.06 per trawl was the highest since 1987. This was an increase from the all-time annual mean low of 0.22 fish per trawl in 1994. The 1998

[2]Annual mean catch per trawl is the total number of fish of a particular species captured in all the trawls in a 1-year period, divided by the total number of trawls done in that year. For example, 12 delta smelt were captured in all the trawls in 1996, and 252 trawls were done in that year. The resulting annual mean catch per trawl is 12÷252 or 0.05.

level of 1.24 was similar to levels seen in 1984 (1.33).   The annual mean catch per beach seine haul from 1995-1998 have been the highest levels since 1983 and 1987. It should be noted that these numbers are primarily young of year and reflect splittail breeding both within and recruitment from outside the marsh.

Figure X-15. Catch per unit effort, delta smelt, 1980-1998

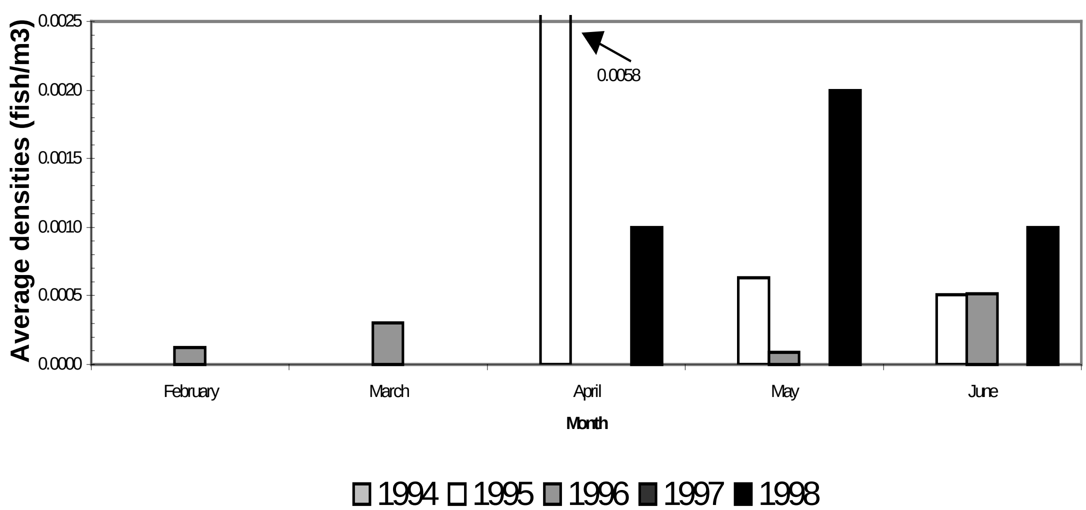


Figure X-16. Average densities of larval splittail by month, 1994-1998

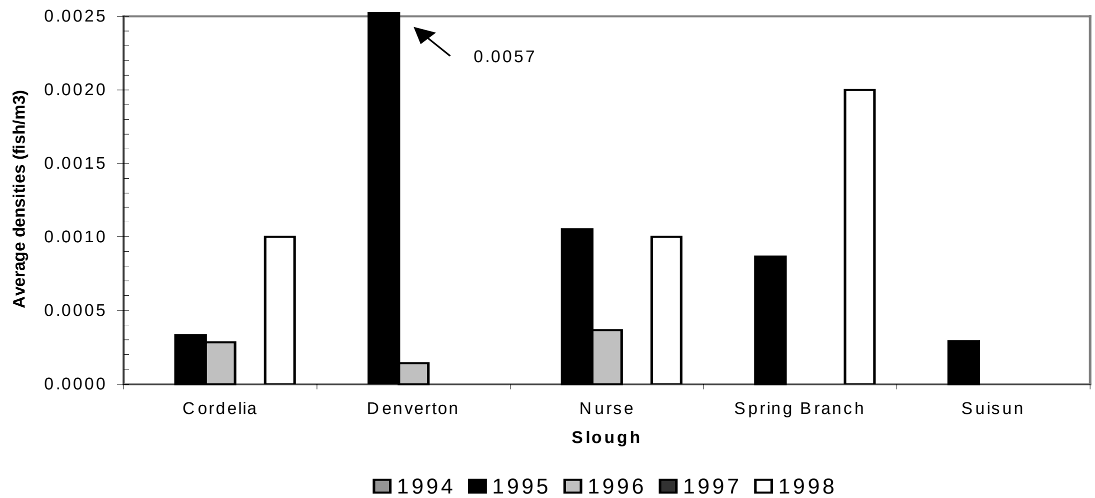


Figure X-17. Average densities of larval splittail by slough, 1994-1998

Table X-3. Range of densities of larval splittail in Suisun Marsh, 1994-1998

	Month	February	March	April	May	June
1994	Minimum (fish/m3)			0	0	0
	Maximum (fish/m3)			0.017	0.017	0
1995	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.064	0.018	0.009	0	0
1996	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.330	0.122	0.050	0.058	0.009
1997	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.727	1.947	0.426	0.052	0
1998	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0	0.023	0.025	0.011

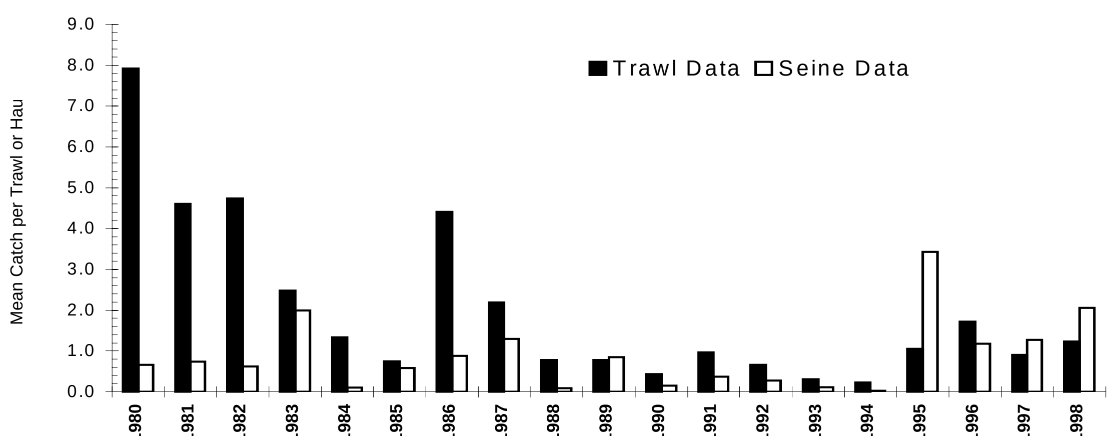


Figure X-18. Catch per unit effort of splittail, 1980-1998

d. Longfin Smelt. Data collected in the larval fish survey indicate that longfin smelt use the marsh for spawning and/or rearing. Researchers generally captured larval longfin smelt in all sloughs sampled (Figure X-19). They caught the highest average densities of larval longfin smelt in Cordelia Slough in 1995-1998, and in Spring Branch in 1994. From 1994-1998, average abundance peaked in February or March (Figure X-20 & Table X-4).

In 1980-1985, longfin smelt abundance fluctuated widely at higher levels than seen in the late 1990s (Figure X-21). The highest annual mean was in 1980, at 7.16 per trawl. Annual mean catch fluctuated at levels higher than 1.00 until 1985, remained below 1.00 through 1989, increased to 1.29 in 1990, and declined to 0.33 or less through 1998. No longfin smelt were caught in the beach seines since 1995. It is difficult to determine if fluctuations in longfin smelt abundance are due to poor survival or migration to other areas in the estuary (Schroeter and Moyle 2000).

In the early years of sampling, 1980-1983, longfin smelt were caught in the marsh during the fall and winter as adult upstream migrants. From 1984-1993, researchers captured most longfin smelt as newly spawned outmigrants in the spring. However, in 1995-1998, they captured longfin smelt in August through February, with most captured in October and November.

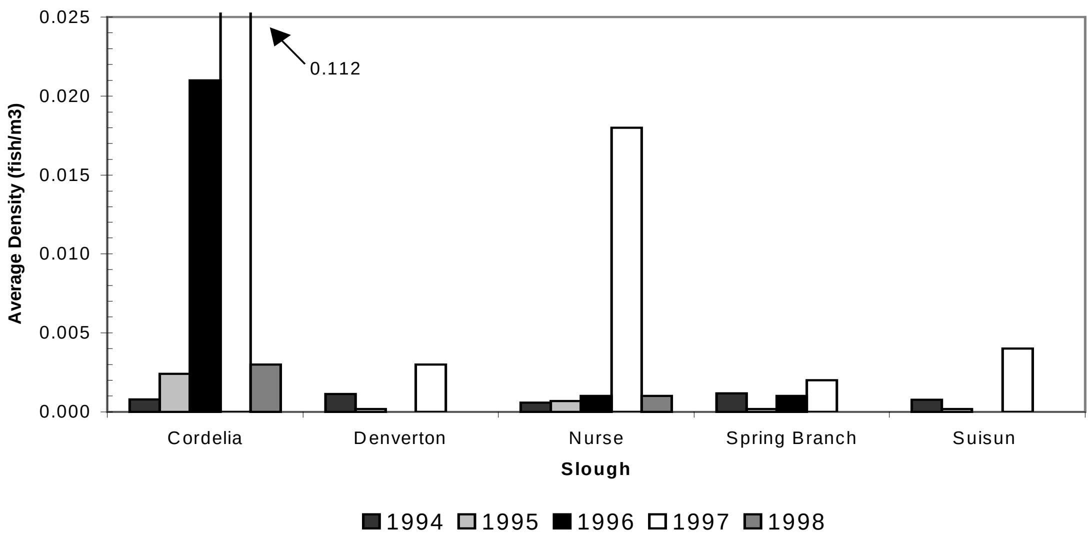


Figure X-19. Average densities of larval longfin smelt by slough, 1994-1998

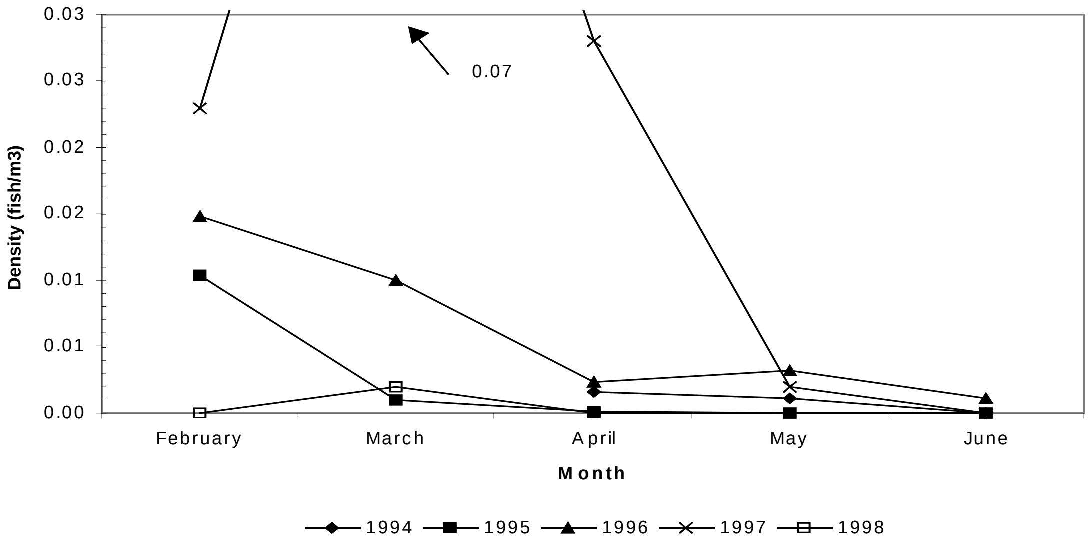


Figure X-20. Average densities of larval longfin smelt in Suisun Marsh, 1994-1998

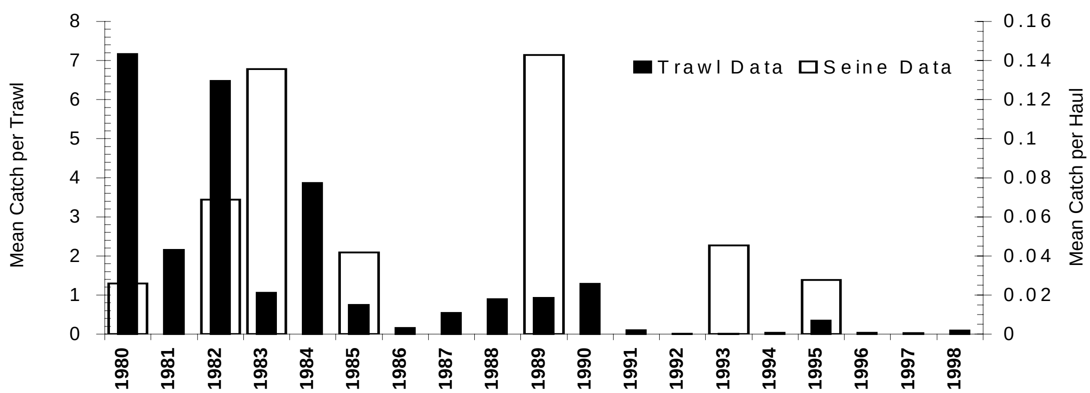


Figure X-21. Catch per unit effort, longfin smelt, 1980-1998

Table X-4. Range of densities of larval longfin smelt in Suisun Marsh, 1994-1998

	Month	February	March	April	May	June
1994	Minimum (fish/m3)			0	0	0
	Maximum (fish/m3)			0.017	0.017	0
1995	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.064	0.018	0.009	0	0
1996	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.330	0.122	0.050	0.058	0.009
1997	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0.727	1.947	0.426	0.052	0
1998	Minimum (fish/m3)	0	0	0	0	0
	Maximum (fish/m3)	0	0.080	0.008	0	0

d. Striped Bass
For an in-depth analysis of striped bass trends see the Striped Bass section in this chapter.

e. Additional Analysis. As discussed later in this report, studies have been conducted to determine the impact of SMSCG operations on salmonid migration, as well as the effect that the physical presence of the gates may have on fish predation in the marsh. Other potentially beneficial or detrimental impacts to the Suisun Marsh fish community could result from changes in salinity due to operation of the SMSCG.

A recent analysis (DWR 1999) of the relationship between salinity and larval, juvenile and adult fish in the marsh concluded that operation of the SMSCG likely benefits spawning and larval fishes during dry and critical years by freshening the marsh for the critical February through June spawning season. (Although gate operations only occur through May, operations during this month influence salinity concentration in June.) Scientific literature indicates that critical periods exists for many spawning and larval fish between February and June, during which time many fish species native to the marsh may be sensitive to higher salinity levels (Wang 1986, Moyle 1976, Unger 1994, CUWA 1994, SFBAEWGP 1997). Thus, it is considered important to maintain low salinity conditions for spawning and larval rearing (generally between 0-5 ppt.) during this period in order to support native fish species in the marsh (Moyle 1998 personal communication; see “Notes”; Baxter 1998 personal communication; see “Notes”). Examination of marsh salinity data indicates that optimal salinity for spawning occurs a relatively high percentage of time during wet years, but much less often during dry and critical years (Table X-5).

Table X-5. Percent of time salinities were greater than 5.0 ppt in Suisun Marsh

Month	Wet Year (ppt)		Dry Year (ppt)		Critical Year (ppt)	
	5.1-10.0	10.1-14.0	5.1-10.0	10.1-14.0	5.1-10.0	10.1-14.0
Feb	0	0	5	0	32	1
Mar	0	0	4	1	24	0
Apr	0	0	8	0	8	0
May	1	0	14	0	29	0
Jun	8	0	33	10	44	10

source: DWR 1999

Gate operations may play an important role in freshening the marsh for spawning during dry and critical years. Gate operations can decrease salinities from west to east in the marsh from 0.4 - 4.9 ppt on average (DWR 1997d). Therefore, gate operations occurring when salinities measure from 0 to 10 ppt in February-June could be effective at decreasing marsh salinities below critical spawning levels in the eastern marsh.

The literature also indicates that adult and juvenile native fish found in the marsh have broad salinity tolerance ranges. This suggests that adult and juvenile fish would not be impacted by changes in salinity during most of the year (Wang 1986, Moyle 1976, Unger 1994, CUWA 1994). However, it has also been hypothesized that increases in the relative abundance of introduced fish in the marsh may be linked to the frequency with which freshwater conditions prevail during fall (Moyle and Herbold 1983, Moyle and Herbold 1986). SMSCG operations decrease the natural variability of the salinity regime in the marsh. Moyle and Herbold (1983) hypothesize that maintenance of an annual fluctuating regime, plus an occasional high salinity year may be necessary to maintain the native fish of the marsh. Although recent analyses by UCD suggest that interactions between introduced fish species and natives species do not play a major role in determining native fish abundance in the marsh (Matern 2001 personal communication; see “Notes”).

It has also been hypothesized that gate operations may effect water temperatures in the marsh. No analysis to date has specifically examined the impact of gate operations on water temperature. However, UCD researchers examined the relationship between fish species and temperature in dry years before and after gate operation began and found no obvious differences in the relationship (Matern 2001 personal communication; see “Notes”). They used a sum of squares – simultaneous test procedure (Sokal and Rohlf 1995) to compare the differences in average monthly slough temperatures by year. Temperature did not vary significantly among sloughs. While this analysis did not specifically compare the temperature in one slough to another in a specific month or year, it is likely that any long-term differences between sloughs would have been evident.

6. Conclusions

It is likely that the trends exhibited in the UCD Suisun Marsh data reflect the overall health of the fisheries resources in the marsh. It is not possible to determine direct impacts of gate operation on this scale. Overall, trends indicate a decline in fish abundance in the marsh. However, these trends may reflect large scale ecological processes occurring in the San Francisco Estuary in general, such as changes in trophic dynamics and food availability due to establishment of invasive species (i.e. *P. amurensis*), and outflow conditions.

7. Recommendations

The UC Davis Suisun Marsh Fish Sampling and Larval Survey programs provide valuable data on trends in fish abundance in the marsh. DWR should continue funding these programs so that these long-term data sets can be maintained and our understanding of factors affecting fish abundance and distribution in the marsh can continue to evolve. This information has also proven useful for other marsh projects and investigations, such as the Suisun Ecological Workgroup, Western Suisun Marsh Salinity Control Test, the Suisun Marsh Preservation Agreement Amendment 3 Biological Assessment, and the Morrow Island Distribution System Maintenance Dredging.

However, these monitoring data cannot be used to directly address the question of whether the gates are impacting the distribution and abundance of Suisun Marsh fishes. Therefore, with the concurrence of the ACOE and BCDC, DWR proposes to eliminate reporting on the UC Davis Suisun Marsh Fish Sampling Program findings as part of DWR’s permit compliance requirements. In lieu of this, DWR will forward all future UC Davis Suisun Marsh Fish Sampling Program annual reports directly to the ACOE and BCDC.

F. Chinook Salmon Smolts

1. Introduction
The ACOE permit and the 1993 NMFS Biological Opinion required the DWR and USBR to determine the diversion rate of juvenile salmon into Montezuma Slough, and the predation rate of juvenile salmon at the structure. To address these issues, DWR and USBR proposed monitoring that began in 1987 and would continue for 3 additional years. The purpose of the monitoring was to determine how many smolts use Montezuma Slough as a migration pathway and estimate losses associated with the SMSCG. A hydroacoustic study was also proposed to determine if behavior of both predators and prey can be monitored.

2. Hydroacoustic Study
The following summary is taken directly from IEP (1990). Fish near the SMSCG were monitored from May 1 to May 22, 1989 using both fixed-aspect and mobile-survey hydroacoustic sampling. Stationary arrays of transducers were positioned immediately upstream and downstream of the structure to determine fish movement and behavior, while mobile transects of the channel were made for a half-mile on either side of the structure for fish distribution and abundance. The SMSCG were not operating during this period and data were to be used for comparison with a period when the structure was operating.

We spoke to DFG staff who carried out the hydroacoustic study and no record can be found of any analysis. The outcome of the study is unknown at this time.

3. Migration Pathway Study and Predation Losses Study

a. Methods
Biologists from the U.S. Fish and Wildlife Service (in 1987, 1992 - 1994) and Department of Fish and Game (in 1994) sampled in Montezuma Slough and Chipps Island. Trawling dates and catches are shown in Table X-6. Sampling techniques in all years were similar to the standard midwater trawl methods employed at Chipps Island. The net used at Chipps Island is 6.0x3.4 meters with a 20.4 m^2 mouth area. The net used in Montezuma Slough is 2.4x2.3 meters with a 5.5 m^2 mouth. The gear used at Chipps Island sampled a cross sectional area of about 0.77% of total width; a cross sectional area of 5% of total width was sampled in Montezuma Slough (NMFS 1994).

In 1987 and 1992, each survey consisted of four 20-minute tows per day at sites shown in Figure X-22. In 1987, Fish and Wildlife Service researchers trawled downstream of the proposed structure site. In 1992, they trawled downstream of the gates, which were operating full bore. In 1993, each survey consisted of five tows above and five tows below the control structure and ten tows at Chipps Island. All trawls were 20 minutes long. The SMSCG did not operate during this period, but the flashboards were in place. Two of the control gates were operating full bore during the 1994 sampling by Department of Fish and Game staff. The third gate was closed for repairs. Fish and Game researchers generally trawled six times above and below the gates for 20 minutes per trawl, but there were some exceptions (Table X-7). On each sampling day in 1994, the Fish and Wildlife Service biologists trawled ten times for 20 minutes each at Chipps Island.

Raw catches were expanded for width and/or for sampling time to calculate the percentage of outmigrant salmon traveling through Montezuma Slough versus those traveling past Chipps Island. The following formulas were used:

- $\frac{\text{raw catch at Chipps Island}}{0.0077}$ = expanded catch at Chipps Island
- $\frac{\text{raw catch in Montezuma Slough}}{0.05} \times \frac{\text{total sampling time at Chipps Islands}}{\text{total sampling time at Montezuma Slough}}$ = expanded catch at Montezuma Slough
- Percentage of outmigrants using Montezuma Slough = $\frac{\text{expanded catch at Montezuma Slough}}{\text{expanded catch at Chipps Island}} \times 100$

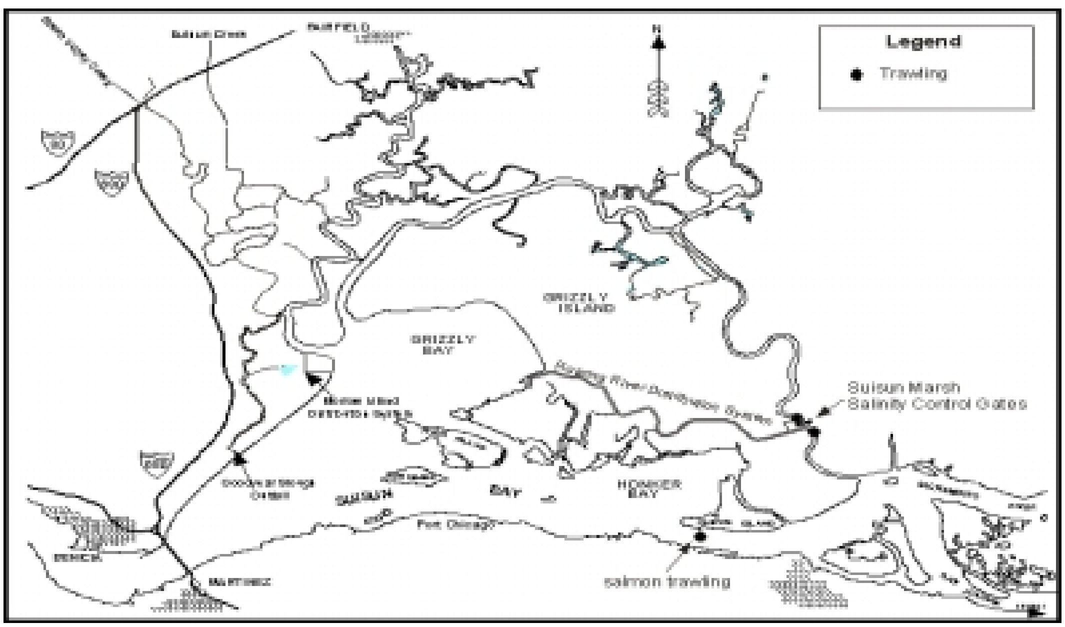


Figure X-22. Location of juvenile salmon trawling in Montezuma Slough and at Chipps Island

b. Migration Pathway Study

Data Limitations*.* Interpretation of the data results are confounded by several factors:

- Smolt use of Montezuma Slough varied by year. NMFS (1994) reported that outmigration patterns vary according to water year type and streamflow patterns. The 1987 water year was dry, 1992 was critical, 1993 was above normal and 1994 was critical.
- The study only contains one pre-project year of sampling, thus natural variability in outmigration numbers is unknown.

- Sampling was not adequate to show the difference in fish use before the gates were installed (1987) and after the gates were in place (1993/1994).
- Gate operations varied between years. In 1992 and 1994, the gates were operated during sampling. They were not operated in 1993.
- Because of the differences in gate operation between years, flow into Montezuma Slough may have varied as well.
- Sampling locations changed. To estimate the use of Montezuma Slough by juvenile chinook salmon, trawling was done upstream of the SMSCG in 1993/1994 but downstream in 1992.
- The midwater trawl gear sampled a cross-sectional area of about 0.77% of the water column at Chipps Island and 5% in Montezuma Slough. Expanded catches assume that salmon are evenly distributed throughout the water column and across the channel. The USFWS samples in 3 lanes across the channel to avoid bias due to any patchiness in salmon migration.

Results. The average estimated percentage of juvenile salmon that migrated out of the Sacramento-San Joaquin Delta and used Montezuma Slough was 0.81% in 1987, 0.76% in 1992, 2.49% in 1993, and 1.40% in 1994. (Estimated daily percentage is shown in Table X-6.)

Department of Water Resources researchers performed a Mann-Whitney U-test on the average estimated percentages of juvenile salmon using Montezuma Slough in 1993/1994 versus 1987. The analysis suggested a significant difference in the numbers of outmigrant salmon using the slough in 1993 ($z=3.18$, $p<0.05$) relative to 1987. However, the 1994 average estimated percentage using Montezuma Slough showed no significant difference when compared with 1987 numbers ($z=1.42$, $p>0.05$). No statistical comparison could be made for 1992, because trawling was done downstream of the Suisun Marsh Salinity Control Gates.

Conclusions. Little information is available on how conditions in Suisun Bay and Suisun Marsh may affect winter-run salmon. The extent that winter-run salmon use Montezuma Slough, as opposed to Suisun Bay, as a migration route is unknown. Other outmigrating races are used as surrogates for winter-run fish because of winter-run's endangered status. We assume that use of Montezuma Slough by the winter-run race would not be different from other outmigrating races.

Overall, numbers of juvenile salmon using Montezuma Slough as a migration corridor may have increased since 1987. Although the average 1993/1994 percentage using Montezuma Slough was above the 1987 average, sample sizes in post-project years were much smaller than the pre-project year, and one post-project year showed a significant difference from the average percentage in 1987. Based on the results from 1992-1994, the average percentage of juvenile chinook salmon that may be using Montezuma Slough as a migration pathway was a maximum of 2.5% to a minimum of 0. The extent that this differs from natural variability in outmigration patterns is unknown because only one year of pre-project data is available.

Table X-6. Midwater trawl catch at Chipps Island and Montezuma Slough upstream and downstream of the SMSCG in 1987, 1992, 1993 and 1994. (Chipps Island catches expanded for channel size. Montezuma Slough catches expanded for time and channel size.)

1987	*Expanded Catches* Chipps Island	Montezuma Slough	Total	% Outmigrants using Montezuma Slough
April 6	658		658	0.00
April 7		0		
April 8	1711		1711	0.00
April 9		0		
April 14		40	7014	0.57
April 15	6974			
April 16		60	8218	0.73
April 18	8158			
April 21	10658	100	10758	0.93
April 23	25658	60	25718	0.23
April 28	24342	100	24442	0.41
April 29	22632	260	22892	1.14
April 30	43289	560	43849	1.28
May 1	30132	400	30532	1.31
May 2	46136	460	46776	0.98
May 3	67895	260	68155	0.38
May 4	38947	300	39247	0.76
May 5	47632	260	47892	0.54
May 6	45526	660	46186	1.43
May 7	58816	340	59156	0.57
May 8	55526	140	55666	0.25
May 9	27368	440	27808	1.58
May 10	59474	100	59574	0.17
May 11	35789	0	35789	0.00
May 12	30526	240	30766	0.78
May 13	43421	360	43781	0.82
May 14	20921	260	21181	1.22
May 15	15132	140	15272	0.92
May 19	35789	0	35789	0.00
May 21	19474	340	19814	1.72
May 26	4342	60	4402	1.36
May 28	5000	140	5140	2.72
Total	832106	6080	838186	0.73

1992[a]	*Expanded Catches* Chipps Island	Montezuma Slough	Total	% Outmigrants using Montezuma Slough
April 20	104737	200	104937	0.19
April 21	146974	620	147594	0.42
April 22	215789	720	236509	0.33
April 23	155263	1560	156823	0.99
April 24	123553	620	124173	0.50
April 27	77105	1220	78325	1.56
April 29	83684	1100	84784	1.30
April 30	68816	360	69176	0.52
May 1	95395	960	96355	1.00
Total	1071316	7360	1078676	0.68

1993[b]	*Expanded Catches* Chipps Island	Montezuma Slough	Total	% Outmigrants using Montezuma Slough
May 12	26974	360	27334	1.32
May 13	43289	640	43929	1.46
May 14	57632	760	58392	1.30
May 17	39474	520	39994	1.30
May 18	28185	1000	29185	3.43
May 19	25000	1360	26360	5.16
May 20	23553	560	24113	2.32
May 21	37500	80	37580	0.21
May 24	14737	880	15617	5.63
May 25	15658	440	16098	2.73
Total	312002	6600	318602	2.07

1994[b]	*Expanded Catches* Chipps Island	Montezuma Slough	Total	% Outmigrants using Montezuma Slough
April 26	54605	2033	56638	3.59
April 27	70000	629	70629	0.89
April 28	87237	467	87704	0.53
April 29	34605	567	35172	1.61
May 2	14737	400	15137	2.64
May 3	21711	286	21997	1.30
May 4	15789	114	15903	0.72
May 5	12632	133	12765	1.04
May 6	21053	67	21120	0.32
Total	332369	4696	337065	1.39

[a] Montezuma Slough trawling in 1992 was on the downstream side of the Suisun Marsh Salinity Control Gates.

[b] Montezuma Slough trawling in 1993 and 1994 was on the upstream side of the Suisun Marsh Salinity Control Gates

Sources: USFWS 1992, 1994; Mark Pierce 1996 and George Edwards 1996, personal communications, see "Notes".

Table X-7. Juvenile chinook salmon catch in Montezuma Slough upstream and downstream of the SMSCG in 1993 and 1994									
	Upstream of Gates		Downstream of Gates			Upstream of Gates		Downstream of Gates	
1993[a]	Raw Catch	Number of Tows	Raw Catch	Number of Tows	1994[b]	Raw Catch	Number of Tows	Raw Catch	Number of Tows
May 12	9	5	13	5	April 26	61	6	12	9
May 13	16	5	6	5	April 27	22	7	53	6
May 14	19	5	8	5	April 28	14	6	36	6
May 17	13	5	9	5	April 29	17	6	27	6
May 18	25	5	13	5	May 2	6	3	3	3
May 19	34	5	3	5	May 3	10	7	7	6
May 20	14	5	4	5	May 4	4	7	1	6
May 21	2	5	5	5	May 5	4	6	4	3
May 24	22	5	4	5	May 6	2	6	4	6
May 25	11	5	1	5					
Total	165		66		Total	140		147	
Sources: USFWS 1994; George Edwards 1996, personal communication, se "Notes."									
[a] Flashboards were in place and the SMSCG were open.									
[b] Flashboards were in place, one gate was closed, and the other two were operating.									

c. Juvenile Salmon Losses at the SMSCG

Data Limitations. Determining the significance of any loss associated with the presence of the SMSCG is confounded by the varying conditions under which samples were taken. Several factors could influence the results:

- Gate operations varied between years. In 1994, the gates were operated during sampling. They were not operated in 1993.
- Equal numbers of tows upstream and downstream of the gates were not completed in 1994.
- Because the gates were operated in 1994, data were separated into two groups: fish caught when the gates were open and fish caught when the gates were closed. This separation resulted in smaller sample sizes.

Results. To estimate the magnitude of salmon losses associated with the Suisun Marsh Salinity Control Gates, catch data from upstream of the gates were compared to catch data from downstream of the gates. A paired samples t-test for 1993 raw data showed a significant difference ($p=0.012$) in the number of juvenile salmon captured upstream and downstream of the gates (USFWS 1994) (Table X-7). To account for the difference in number of tows per day upstream and downstream of the gates in 1994, catch numbers were expanded for time. To account for the gates operating during the 1994 sampling, catch numbers were analyzed in two groups: number captured with gates open and number captured with gates closed. In 1994, no significant difference ($p=0.05$) was found between catch numbers upstream and downstream of the gates, regardless of gate position.

Conclusions. Sampling upstream and downstream of the Suisun Marsh Salinity Control Gates in 1993 indicated there may be loss associated with the structure (USFWS 1994). Data from 1994 did not corroborate this. However, this may be due to small sample sizes. Results from migration pathway sampling indicate that a maximum average of 2.5% of juvenile chinook salmon may use Montezuma Slough as a migration corridor. Therefore, any impacts from predation at the structure may occur to less than 2.5% on average of all juvenile chinook salmon migrating to the ocean.

Recommendations. The results from the midwater trawl and the predator abundance surveys should be evaluated together. The two studies combined provide a more complete picture of possible impacts to juvenile salmon. See the following section for a complete discussion.

G. Predator Abundance

1. Introduction

The NMFS 1993 Biological Opinion and the ACOE permit require the DWR and the USBR to determine the magnitude and nature of predation losses of juvenile chinook salmon. DFG biologists conducted studies from 1987 through 1993 to determine the presence of predators near the SMSCG. They also examined stomach contents of predators to determine amount of predation of juvenile salmon. Results from these studies have been reported elsewhere (Raquel 1988, 1989, 1990, 1991, 1992; DFG 1994) and summarized in previous annual reports (DWR 1995c, 1997a, 1997b).

2. Methods

Methods from 1987-1993 were generally similar except for the addition of a reference site, night sampling, and electrofishing for prey in 1993. The reference site was 2 miles upstream of the salinity control gates (Figure X-23). The other two sites were within 1/4 mile upstream and downstream of the gates. From 1987 to 1992, adult fish were collected during daylight hours at about two week intervals during May and June. In 1993, stations were monitored for 24 hours a day for two 2-day periods.

DFG staff fished variable mesh gill-nets (200-foot long by 12 feet deep monofilament stationary net and nylon drift net, both with mesh sizes of 2.4 to 4 inch stretch mesh) upstream (Collinsville side) and downstream (Beldon’s Landing side) of the structure (Figure X-23). They used stationary nets to fish near the banks of the slough. At each site, a stationary gill-net was placed for a one hour period and one drift-net was fished for a 20 minute period. Nets were checked at the end of the sampling periods. DFG biologists identified the fish to species and measured fork length in mm, then the nets were moved to the next site downstream.

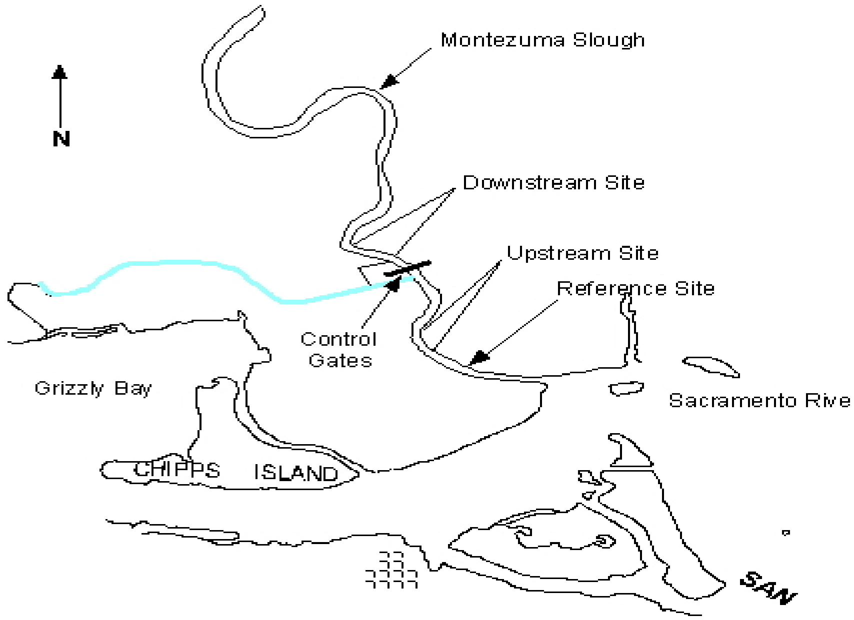


Figure X-23. Location of predator sampling in Montezuma Slough

The stomachs of striped bass and Sacramento pikeminnow 180 mm or greater in length were pumped. Researchers examined stomach contents for juvenile salmon and other prey species. Researchers identified all fish found in stomachs to species level when possible.

Table X-8 shows the status of the SMSCG operations during each year of sampling. For statistical comparisons we considered 1987 to be the control since the structure was not in place during that year of sampling.

Table X-8. Status of SMSCG operations during predation studies in Montezuma Slough

Year	Gate Status
1987	SMSCG were not constructed yet.
1988	Not operating.
1989	Not operating.
1990	Operating during 3 of 5 days of sampling. Everything out of the water during 2 days.
1991	Operating during 9 of 13 days of sampling. Everything out of the water during 4 days.
1992	Operating during 9 of 13 days of sampling. Everything out of the water during 4 days.
1993	Flashboards in place but gates not operated.

For data analyses, striped bass and pikeminnow catches in the gill nets were summarized as catch per hour (CPUE). The data were log(CPUE +1) transformed prior to analyses. For each species, regression analysis was used to determine if there was a relationship between CPUE and sampling year. One-way ANOVA was used to test the hypothesis that CPUE was the same during each sampling year. Tukey's multiple comparison test for unequal sample size was used after a significant ANOVA ($p \leq 0.05$) to determine which years were significantly different from others.

3. Data Limitations

Determining the diet of predatory fish through stomach sampling are confounded by several factors. First, piscivorous predators are known to regurgitate stomach contents when they are captured in gill nets (Bowen 1996). Second, digestion rates in fish vary with water temperature, body sizes of predators and prey, total meal size and meal frequency (Adams and others 1990; Vigg and others 1991). The variation in digestion rates can make it difficult to detect prey, much less determine the importance of various prey in a predator’s diet. Rogers (1991 as cited in DFG 1993) reported that smallmouth bass and northern pikeminnow digest salmon in a few hours. Digestion that occurs after capture but before removal from the net can make identification of prey difficult. This could have influenced results from the gill nets that were collected at hourly intervals. Finally, not all fish in each stomach sample could be identified.

The results are also limited by the study design. Nets were fished up to a ¼ mile from the structure. It is possible that predator concentrations measured more than 100 feet from the structure are a result of factors such as available cover or localized eddies not caused by the structure.

4. Results

Striped bass and Sacramento pikeminnow were the dominant predatory species captured during the sampling in 1987-1993. A regression analysis showed a declining trend in Sacramento pikeminnow CPUE over the seven years of sampling ($p<0.05$, $r^2=0.07$) (Figure X-24). After a significant ANOVA ($P<0.05$), a Tukey multiple comparison test indicated that only CPUEs in 1987 and 1993 were significantly different from each other. Biologists attributed the decrease in Sacramento pikeminnow abundance to increased salinity in Montezuma Slough (DFG 1994). Sacramento pikeminnow are found in freshwater (Wang 1986) and would move upstream as the estuary became more saline.

Striped bass CPUE generally increased through 1992, but then decreased in 1993. A regression analysis indicated that there was increasing trend in striped bass CPUE ($p<0.05$, $r^2=0.03$) (Figure X-25). After a significant ANOVA ($p<0.05$), a Tukey multiple comparison test showed that CPUE levels in 1987 were significantly different from those measured in 1990-1992. However, we do not know if the increase in striped bass levels was a localized increase at the SMSCG or an increase in a larger area of the marsh. The addition of a reference site in 1993, helped to address this question.

DFG (1994) reported that there were no statistical differences in the number of predators (striped bass and Sacramento pikeminnow) captured at all three sites (upstream, downstream and reference site) in 1993; indicating no statistical difference in the CPUE of predators around the gates versus an area two miles upstream. However, the nets upstream and downstream of the structure may not have been close enough to measure predator concentrations caused by the structure. It is not possible to eliminate the possibility that predator abundances measured were due to other factors.

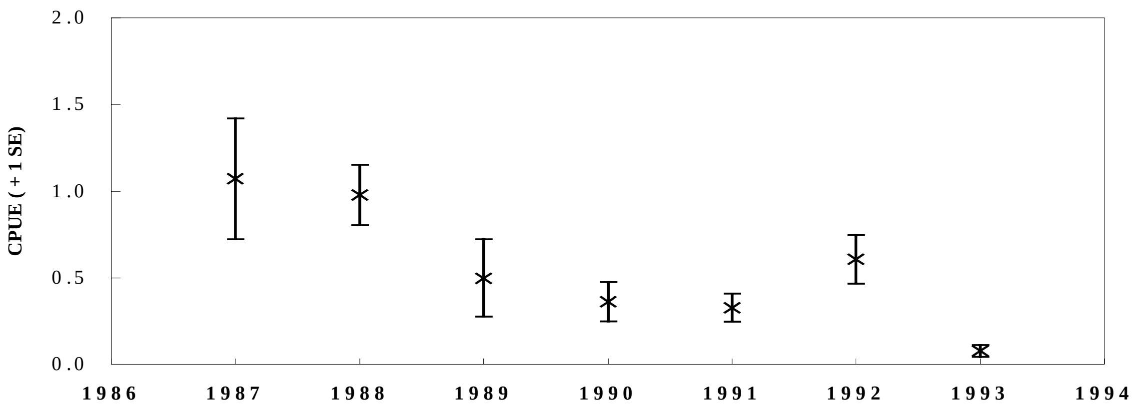


Figure X-24. Sacramento pikeminnow CPUE during the predator sampling at the SMSCG, 1987-1993

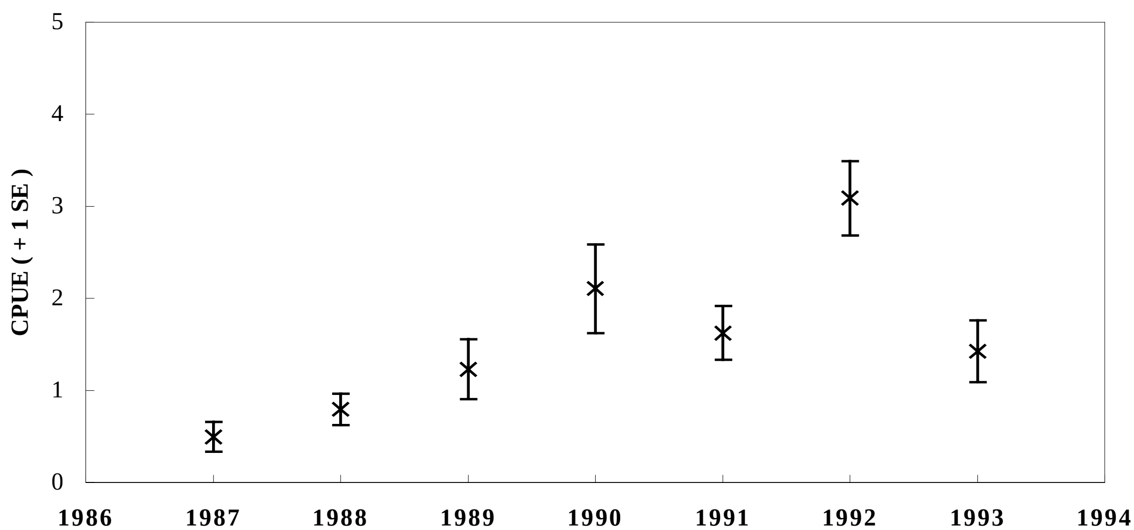


Figure X-25. Striped bass CPUE during the predator sampling at the SMSCG, 1987-1993

Results from the stomach analysis indicate that predation on juvenile salmon was small. From 1987 to 1993, 0.3% of the predator stomachs examined contained juvenile chinook salmon. Results from the midwater trawling in 1987, 1992, and 1993, indicate that juvenile chinook salmon were present in Montezuma during the predator sampling (Table X-9). The juvenile chinook salmon (~3 fish) were found in striped bass stomachs in 1991 and 1992. Other fish species identified in prey fish stomachs over the course of the study were threespine stickleback, chameleon goby, yellowfin goby, prickly sculpin, American shad, threadfin shad, staghorn sculpin, inland silversides, mosquito fish, bluegill, anchovy, brown bullhead and striped bass.

It is possible that chinook salmon were present in predator stomachs and not identified. From 1989 – 1993 unidentifiable fish comprised from 3 – 57% and < 1% – 23%, by volume, of the prey fish found in striped bass and Sacramento pikeminnow stomachs, respectively (Table X-10). In addition, predators may have regurgitated stomach contents when they were captured in the net. A total of 861 stomachs were examined in the 7 years of sampling and 122 of those were empty.

Table X-9. Midwater trawl catches of juvenile chinook salmon in Montezuma Slough during the predator sampling, 1987-1993

Dates of Predator Sampling[a]	Chipps Island Expanded Catches	Montezuma Slough Expanded Catches	Total Expanded Catches	% juvenile chinook traveling in Montezuma Slough
5/8/87	55526	140	55666	0.25
4/24/92	123553	620	124173	0.50
4/30/92	68816	360	69176	0.52
5/12/93	26974	360	27334	1.32
5/13/93	43289	640	43929	1.46
5/18/93	28185	1000	29185	3.43
5/19/93	25000	1360	26360	5.16
5/20/93	23553	560	24113	2.32

[a]Additional days of gill netting were done but no trawling was performed on those days.

Source: USFWS 1992, 1994; DFG 1994

Table X-10. Percent by volume of unidentifiable fish of total prey fish in striped bass and Sacramento pikeminnow stomachs, 1989-1993

Year	Striped bass	Sacramento pikeminnow
1989	9%	23%
1990	17%	10%
1991	3%	6%
1992	N/A	N/A
1993	57%	< 1 %

N/A: Data from 1988 and 1992 are not available.

Source: Raquel 1990, 1991, 1992; DFG 1994.

5. Conclusions

Sampling from 1987-1993, indicate that striped bass and Sacramento pikeminnow CPUE at the SMSCG has not significantly increased. However, it is not clear that the CPUE's can be directly linked to the presence of the SMSCG. Stomach analyses indicate that striped bass prey on juvenile chinook salmon at low levels. Results from migration pathway sampling indicate that less than 2.5% of juvenile chinook salmon may use Montezuma Slough as a migration corridor. Therefore, studies to date indicate that impacts from predation at the SMSCG appear to be minimal.

DWR staff acknowledge that there are limitations in our ability to estimate numbers of outmigrating salmon at Chipps Island and within Montezuma Slough. We also acknowledge that these studies, as designed, can not directly link the presence or operation of the SMSCG with either salmon outmigration or predation rates. The migration pathway study attempted to put any predation rate information in perspective: "What percentage of outmigrants are likely to encounter predation at the SMSCG?" However, given the endangered and threatened status of two runs of Chinook salmon within the Sacramento-San Joaquin Estuary even minimal predation could be considered significant. Additionally, only one year of data is available (1993) to provide a perspective on what predation rates away from the structure are likely to be. One year of reference data may not be adequate for determining if predation at the SMSCG has increased, especially given the limitations inherent in stomach analyzes.

6. Recommendations

DWR staff recognize the importance of determining predation rates at the SMSCG to the satisfaction of the regulatory agencies. We recommend that the SMSCG Steering Group review the predation study results through 1993 and develop additional studies that will more fully address agency concerns.

H. Adult Chinook Salmon

1. Introduction

The NMFS 1993 Biological Opinion and the ACOE permit require the DWR and the USBR to determine magnitude and nature of delays to adult Chinook salmon. Information gathered during the predator abundance studies indicated that adult salmon may be affected by gate operation. The DFG, with the assistance of the DWR, conducted studies in 1993 and 1994 to determine:

- if gate operation affected the percentage of adult salmon moving through the structure, and
- if gate operation affected the time it takes adult salmon to move through structure.

The methods and results from the 1993 and 1994 studies have been reported and summarized elsewhere (Tillman and others 1996; Edwards and others 1996; DWR 1997b). Briefly, the results of the 1993 and 1994 Adult Salmon Migration Studies indicate that operation of the SMSCG delays and block the upstream migration of salmon. The SMSCG Steering Group concluded it was not possible to quantify the absolute delay related to the SMSCG, however, at a minimum, when operating, the SMSCG blocks the Montezuma Slough migratory route for all runs of chinook salmon for 12 hours each tidal cycle (6 hours two times a day).

The SMSCG Steering Group examined a number of options for providing unimpeded passage including horizontal slots or holes, vertical holes, a ladder, and modifying gate operations (DWR 1997c). After much discussion, and although the group was not able to base the decision on hard science, they selected the horizontal slot option as likely to succeed. Also, based on the method of creating the slot by using spacers between existing flashboard sections, this option would provide a balance between the benefit and cost.

Following the conception of the modification of the flashboards, the DWR proceeded to design and implement the modification. A flashboard was removed entirely and two sets of spacers were used to create two slots. These slots are each three-feet high, sixty-six feet long, and provide passage opportunities at two different depths. The spacers are removable so that the original configuration can be compared to the flashboard modification as well as the configuration of the SMSCG with the flashboards removed.

The Department of Fish and Game, with the assistance of the Steering Group, designed and implemented a three-year evaluation of the flashboard modification. The goal of the evaluation is to determine if the modification is effective in increasing the passage rate of salmonids migrating through Montezuma Slough. The first year of the study occurred in 1998 and the second year in fall 1999.

2. Methods

The following provides a brief summary of the methods used in the 1998 and 1999 studies. Please see Edwards & Fujimura (1998, 1999) for a complete description. Under each of the three SMSCG operational configurations, 66 adult fall-run salmon were fixed with sonic tags and tracked to compare migration times, proportion (percentage) of fish passing, and patterns of passage though the SMSCG. Table X-11 shows the schedule for the three phases of the evaluation in 1998 and 1999.

Table X-11. Schedule for the 1998 and 1999 salmon passage evaluation at the SMSCG

1998	1999	SMSCG Configuration
Oct.1-12	Sept. 27-Oct. 13	Regular flashboards installed, gates operating, boat lock operating
Oct.15-26	Oct. 14 – Nov. 4	Flashboards and gates out of the water, boat lock operating
Oct. 29 – Nov. 10	Sept. 14 - 26	Modified flashboards installed, gates operating, boat lock operating

Eighteen of sixty-six fish and eight of sixty-six fish per phase were tagged with depth tags in 1998 and 1999, respectively. Researchers reduced the number of depth tags in 1999 because of noise interference in the depth tag frequency. After tagging, the fish were released about 0.5 miles downstream of the SMSCG. Hydrophones and receivers were set up upstream and downstream of the SMSCG to continuously monitor for tag signals.

3. Data Limitations

Determining the affect of SMSCG operation on the passage of adult salmon may be confounded by several factors. These factors include:

- handling stress, which can influence the behavior and physiology of fish;
- noise interference, which may mask depth tag signals and make determining depth at passage very difficult;
- milling behavior, the extent of natural milling in Montezuma Slough is unknown;
- changing water conditions over the course of the study; and

- within run variation in migratory behavior.

4. Results
Results from 1998 and 1999 salmon passage studies indicate that the modified flashboards are not improving salmon passage at the SMSCG (SMSCG Technical Team 2001). The smallest number of fish passed the gates during the modified operation phase in 1998 and 1999. These numbers are significantly less than in the other two phases ($P<0.05$). Salmon took significantly longer to pass the gates during the modified flashboard phase than the other two phases in 1998 ($P<0.05$) but not in 1999.

Ten environmental factors which may have influenced salmon passage at the gates were also analyzed by the SMSCG Technical Team[3]. The environmental factors (flow, water temperature and dissolved oxygen, for example) were not a significant influence on salmon passage. The Technical Team concluded that the modified flashboards hampered salmon passage and that to improve passage, the focus must shift back to the structure itself.

The SMSCG Steering Group agreed with the findings of the SMSCG Technical Team and evaluated several options for salmon passage. The Group decided to see if salmon will use the boat lock to pass through the structure by leaving the boat lock open, except for when boats need to pass. The three study scenarios (in no particular order) will be

- full bore operation, regular flashboards, and boat lock closed,
- everything out of the water, and
- gates operating, regular flashboards installed and boat lock open all the time (except for boat passage).

The Group also agreed that at least two years of the study will be completed before another option is pursued. The first year of the open boat lock salmon passage study will be conducted in fall 2001.

5. Recommendations
DWR staff do not recommend any changes to the actions the SMSCG Steering Group is pursuing.

I. Striped Bass Egg and Larva Survey

1. Introduction
This element of the Suisun Marsh Monitoring Program was designed to meet the requirements of the BCDC permit, specifically with respect to determining age class, resources and abundance of striped bass eggs and larvae. In order to assess whether gate operations would reduce the abundance of striped bass egg and larva in the marsh, the Monitoring Plan proposed that the Montezuma Slough egg and larva stations would be monitored for an additional 3 years once operation of the SMSCG was initiated. The data analysis was to consist of comparing the abundance index for Montezuma Slough with that of the Delta at large to determine whether abundance trends are similar.

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[3] The SMSCG Technical Team is a subgroup of the SMSCG Steering Group. The Technical Team is made up of staff from DFG and DWR and is charged with implementing salmon passage studies and analyzing data collected at the SMSCG.

2. Methods

The egg and larval survey provides an abundance index of developing striped bass through the spawning season. Striped bass spawning is triggered by water temperature, so egg and larval survey dates vary from year to year between February through July.

In years before 1991, the survey was initiated early enough to collect eggs and larvae from early striped bass spawning. In 1991, sampling was done weekly from February through mid-July to encompass the delta smelt spawning period. Beginning in 1992 at Suisun Marsh and Suisun Bay sites, sampling was conducted every 4 days. In 1995, sampling frequency was decreased to every 8 days at these sites.

To collect the samples, 10-minute oblique tows were made at each station. The net used to collect the samples is 3.18 meters long and is made of 500-micron mesh.

Until 1995, sampling occurred throughout Suisun Marsh, Suisun Bay, the Delta and the Sacramento River. In 1995, several sampling stations were eliminated, in particular those in Montezuma Slough. Delta wide sampling for eggs and larva for striped bass was discontinued for three reasons: (1) researchers believed that little additional information could be gained by continued sampling at all original sites; (2) the egg and larva surveys are expensive; (3) analysis of the data collected was lagging due to the intensity of the field program. Resources were thus redirected to finalize data analysis and complete reports. Figure X-26 shows past and present sampling stations.

3. Data Limitations

Though egg and larval sampling was to be conducted at Montezuma Slough sites for three additional years following initiation of SMSCG operations in 1988, sampling was not initiated at these sites until 1993. Sampling occurred in Montezuma Slough in 1993, 1994, and 1995. However, larvae collected in 1995 were not measured. Consequently, biologists were not able to calculate abundance indices for 6 – 14 mm striped bass. Further, as mentioned above, sampling stations in Montezuma Slough were eliminated from the sampling regime. Thus, only two years of post-gate operation egg and larval data are available. Analysis and interpretation are limited by the lack of available data.

Data analysis is limited to comparisons of the egg and larval abundance trends in Suisun Marsh with those of the Delta. It is not possible to determine whether SMSCG operations impact the abundance of striped bass eggs and larva from these data. To establish a definitive link between gate operations and egg and larval abundance, it is necessary to compare spring-time abundances with and without gate operations during the same year. Since a “no-gate operation” data set does not exist, it is not possible to establish a causal relationship between gate operations and abundance of striped bass egg and larva.

4. Results

In comparison to the total Delta index, the Montezuma Slough index comprises a small proportion of total 6-14 mm larval abundance estimated by the survey. However, any area suitable for rearing larval striped bass is important to the estuary’s low population. In 1993, the striped bass egg and larva survey was conducted throughout the Delta, including stations in Montezuma Slough for the first time since 1988. Abundance indices since 1984 are shown in Table X-12. Larvae collected in 1995 were not measured and consequently no abundance indices were calculated for 6-14 mm striped bass. Sampling in Suisun Marsh was not conducted after 1995.

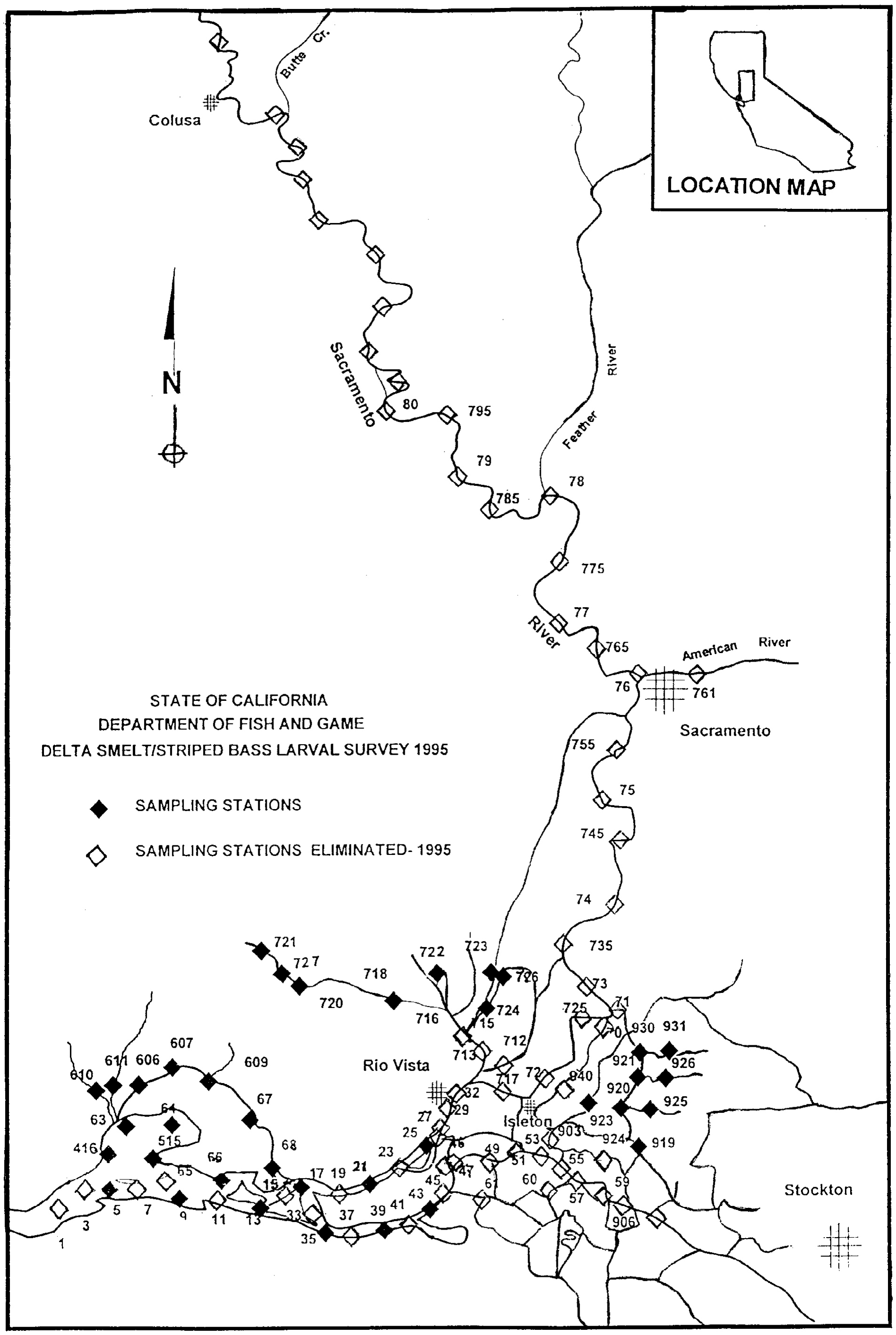

Figure X-26. Delta smelt and striped bass larva survey sampling stations

A 1987 Department of Fish and Game study concluded that the SMSCG would have minimal effect on striped bass eggs and 3-6 mm larva (Raquel 1988). Results suggest that spawning occurs well upstream of the mouth of Montezuma Slough. At the station farthest upstream from the Suisun Marsh Salinity Control Gates, eggs were found on only one sampling run. At the downstream station, no 3-6 mm larva were found. Based on the limited data available, it appears that the gates are not affecting striped bass egg and larval development.

During pre-project years, 6-14 mm eggs and larva in Montezuma Slough comprised 0.04-0.20% of the total eggs and larvae in the Delta. In 1993, abundance in Montezuma Slough comprised 2.00% of total egg and larval abundance in the Delta. This is likely because 1993 was an above-normal water year, and the larvae were washed downstream by high flows. In 1994, abundance in Montezuma Slough was 0.28% of total egg and larval abundance in the Delta. This is similar to levels seen in preproject years.

Table X-12. 6-14 mm striped bass abundance indices
(abundance x 10,000)

Year	Total Index	Montezuma Slough
1984	640,000	1,400
1985	1,400,000	1,800
1986	1,900,000	2,000
1987	[a]	900 [b]
1988	570,000	240
1989	1,211,570	NS[c]
1990	480,055	NS
1991	399,368	NS
1992	414,288	NS
1993	980,224	20,312
1994 [d]	628,048	1,760

Source: Department of Fish and Game. All values subject to revision.
[a] No Delta-wide survey.
[b] 3 to 14 mm fish.
[c] Not sampled.
[d] No sampling was done in Suisun Marsh after 1995. Data from 1995 will not be processed.

Data from the UC Davis Suisun Marsh Larval Fish Sampling Program, which has been conducted each spring since 1994[4], indicates that striped bass are an important component of the larval fish assemblage found in the marsh (Matern and others 1999). In 1994 -1996 and 1998, the third most abundant family collected during larval sampling was the Percichthyidae, represented by striped bass. In 1997, it was the fourth most

[4] Sampling was conducted from February through June each year, except in 1994, when sampling occurred from April through June.

abundant[5]. Abundances have ranged from 366 individuals in 1994 to 4949 individuals in 1996. Matern and others (1995) assert that catches in 1994 reflect results of a very dry year with lower than average river flows. Suisun Marsh salinities were higher than optimal levels (<1ppt) in April-June, 1994. The average salinity measured 1.9 ppt with a range of 1.1 – 6.5 ppt at all sampling sites.

In 1994, 1996 and 1997 striped bass larva were first collected in April and peaked in abundance in May. In 1995 and 1998, no striped bass larva were collected until May and abundance peaked in June. Spawning generally occurs from April through May and is largely determined by water temperature, flow and salinity (Moyle 1976).

5. Conclusions

Based on the limited data available, it appears that the SMSCG are not affecting striped bass egg and larval development. The abundance of striped bass eggs and larva would not likely be impacted by gate operations during wet or above normal water years, since the gates are rarely operated during the April - May spawning period of such years. For example, gate operation only occurred in April or May once during the five year UC Davis larval sampling program (in 1994). (For more information on frequency of gate operations, please see Chapter 7 of the Final Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan, SWRCB 1999). During dry or critical years, when gate operations would likely continue into May, striped bass egg and larva may benefit from decreased salinities created by gate operations, since optimal salinity for spawning is quite low.

6. Recommendations

We conclude that DWR has met its permit obligation to determine whether impacts are occurring to striped bass larvae. Since gate operations do not appear to be impacting striped bass larvae, DWR proposes to eliminate reporting on the DFG Striped Bass Egg and Larva study as part of DWR's permit compliance requirements. In lieu of this, DWR will forward all future UC Davis Suisun Marsh Larval Fish Sampling Program annual reports to the ACOE.

We recommend the continuation of the UC Davis Larval Survey. Monitoring striped bass larval abundance provides valuable information regarding the status of this important recreational fish. Although the DFG Egg and Larva Survey no longer monitors striped bass abundance in Suisun Marsh, the UC Davis larval survey does, and is actually more extensive in terms of marsh survey sites.

J. Juvenile Striped Bass

1. Introduction

The striped bass tow-net survey provides an index of young-of-the-year striped bass abundance in the Delta and Suisun Bay. This element of the Suisun Marsh Fish Monitoring Program addresses the BCDC permit requirements to study fish abundance and age classes of particular species. The Pre-project Fishery Resource Evaluation

[5] Generally, Cottidae (prickly and staghorn sculpins) and Gobiidae (yellowfin and shimofuri gobies) outnumber the Percichthyidae. Osmeridae (delta and longfin smelt) outnumbered Percichthyidae as well in 1997.

(Spaar 1988) suggested that this element could continue indefinitely and that sampling by UCD would be used to track juvenile striped bass abundance in the marsh.

This element was to be used to determine if operation of the SMSCG adversely affects the use of Montezuma Slough by juvenile striped bass. Data from other estuarine sampling locations is used to determine how other portions of the populations varied. The data analysis consists of comparing the abundance index for Montezuma Slough with that of the Delta at large to determine whether abundance trends are similar.

2. Methods

The striped bass tow-net index estimates the abundance of young striped bass when the average length of the fish is 38.1 mm (1.5 inch). The 38.1 mm size was selected because the tow-net is most efficient for fish of that length. Surveys are conducted every 2 weeks in Suisun Bay and the Delta until the index size is reached or exceeded. Samples are taken during an oblique 10-minute tow at a standardized boat speed. Sampling begins when the young striped bass reach about 17.8 mm and continues until mean catch length is greater than 38.1 mm. Due to variations in environmental conditions, survey dates vary from year to year within the months of June, July, and August. Spring and summer conditions affect spawning time and larval growth and, hence, the time at which young become vulnerable to the sampling gear. Sampling stations are shown on Figure X-27.

3. Data Limitations

Data analysis is limited to comparing abundance trends in the marsh with those in the Delta. As with the striped bass egg and larva survey, it is not possible to determine whether gate operations impact the abundance of striped bass young of the year from these data. In order to establish a definitive link between SMSCG operations and striped bass young of the year abundance, it would be necessary to compare spring-time abundances with and without gate operations during the same year. Since a “no-gate operation” data set does not exist, it is not possible to establish a causal relationship between gate operations and abundance of striped bass young of the year.

4. Results

UC Davis researchers (Matern and others 1999) note over their 20 year sampling program, striped bass, in particular young-of-the-year (YOY) have frequently been the most abundant fish collected during the year. Striped bass was the most abundant fish caught in all years of the UCD study except 1988-1990, 1993, and 1995. Overall, striped bass catch declined from levels in the early 1980s, and annual mean catch ranged from 1.87 to 21.78 (Figure X-28). Annual mean catch per trawl fluctuated at or above 10.40 through 1986. In 1987-1998, the annual mean catch per trawl fluctuated at or below 7.57, except for peaks of 12.92 and 12.03 in 1992 and 1997, respectively. The annual mean catch per haul in 1998 was 1.12, the highest since 1987 (1.30) and 1995-1997 (2.82, 5.64, 22.69).

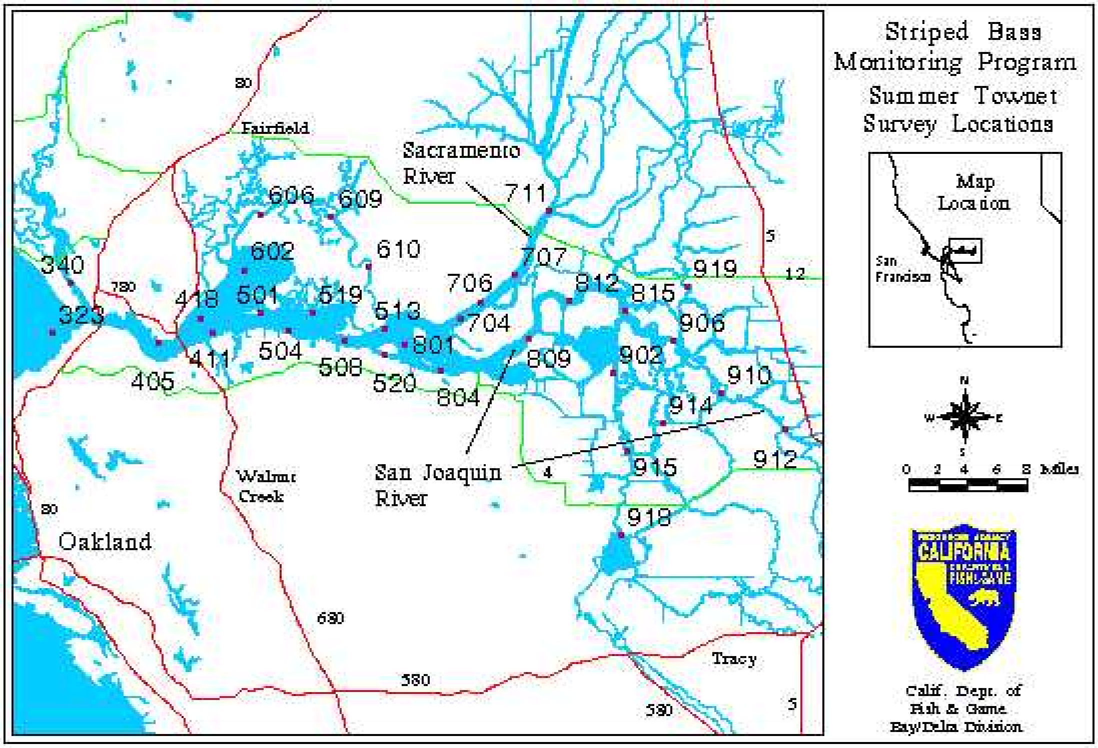

Figure X-27. Striped bass tow-net survey stations (Foss and Miller 1996)

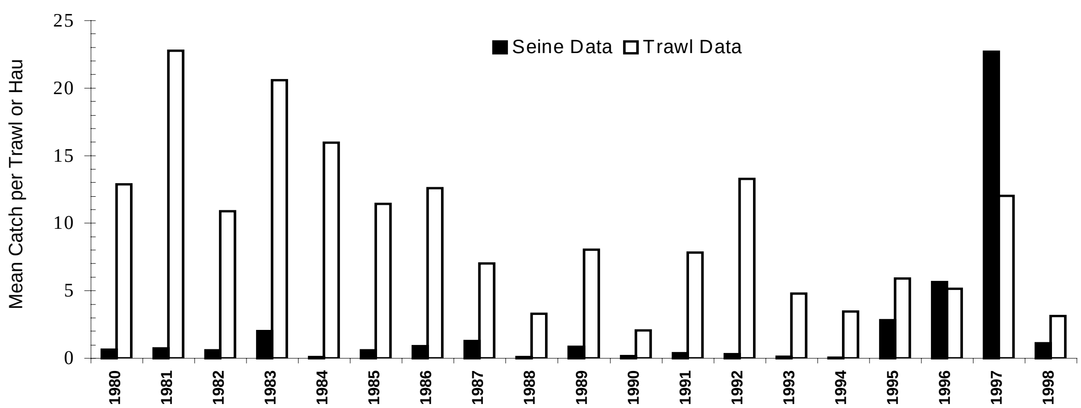

Figure X-28. Catch per unit effort, striped bass, 1980-1998

Since 1959, the striped bass index in Montezuma Slough has ranged from less than 1 to 13, with an average of 4.9 (Figure X-29 and Table X-13). The abundance index in the Delta has ranged from 0.5 to 54.7, with an average of 18.2 (Figure X-30 and see Table X-14). A gradual decrease in the average 38.1 mm striped bass abundance index has been observed in the Delta and Montezuma Slough since sampling began in 1959. The average abundance index in the Delta was 38.5 for 1959-1969, 18.2 for 1970-1979, 8.9 for 1980-1988, and 4.0 for 1989-1998. A decrease has also been observed in Montezuma

Slough, where the average abundance index was 6.9 for 1959-1969, 6.3 for 1970-1979, 4.8 for 1980-1988, and 1.3 for 1989-1998. Since the decrease has been relatively constant over the last 30 years, it is unlikely that changes in abundance were due to installation and operation of the Suisun Marsh Salinity Control Gates. In general, increased abundance during most wet years indicates that Montezuma Slough is a relatively small, yet important habitat for juvenile striped bass.

Tow-net survey results indicate that striped bass young-of-the-year have been unusually low in the Delta since 1995. In the past, variations in striped bass young-of-the-year abundance have usually been a function of outflow, spring runoff, and diversion rates during the spawning season (IESP 1987). However, this relationship did not hold well in 1995. Results of the 1995 tow-net survey indicate that striped bass abundance was unusually low for a wet year, according to Foss and Miller (1996).

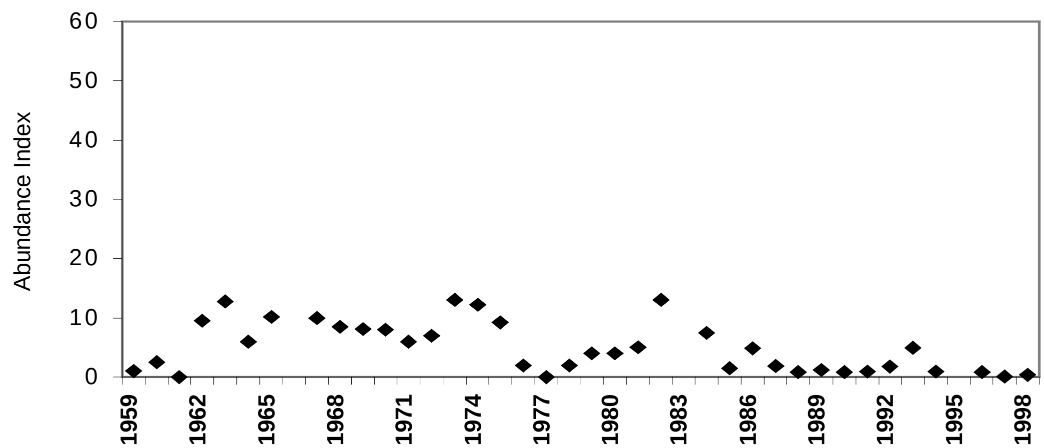

Figure X-29. Striped bass 38.1 mm abundance indices for Montezuma Slough, 1959-1998

Figure X-30. Striped bass 38.1 mm abundance indices for the Delta, 1959-1998

Table X-13. Striped bass abundance indices for Montezuma Slough and the Delta, 1987 – 1998						
	Montezuma Slough Index	Suisun Bay Index	Total Suisun Index	Delta Index	Total Index	38.1-mm Index Date
1984	a	a	20.0	6.3	26.3	13-Jul-84
1985	a	a	4.1	2.2	6.3	16-Jul-85
1986	a	a	41.1	23.8	64.9	9-Jul-86
1987	1.9	3.4	5.3	7.3	12.6	22-Jun-87
1988	< 0.8	< 0.7	0.7	3.9	4.6	24-Jul-88
1989	1.2	0.8	2.0	3.1	5.1	11-Jul-89
1990	0.8	0.6	1.5	2.8	4.3	18-Jul-90
1991	0.9	0.9	1.6	3.9	5.5	25-Jul-91
1992	1.8	2.2	4.0	6.6	10.6	26-Jun-92
1993	4.9	6.9	11.8	10.8	22.6	22-Jul-93
1994	0.9	2.7	3.6	7.0	10.6	10-Jul-94
1995[b]	NA	NA	NA	NA	NA	NA
1996	0.8	0.8	1.6	0.5	2.1	26-Jul-96
1997	0.1	0.5	0.6	1	1.6	16-Jul-97
1998	0.4	0.9	1.3	0.1	1.4	30-Aug-98

[a]Data not available.
[b]No indices were set during Water Year 1995. Please see text for explanation and an estimated value of the Total Index.

Three surveys were conducted in 1996, however, sampling problems rendered data from the first survey unusable. The Delta Index, 0.5, was the lowest on record since 1959 when DFG began calculating indices, while the Montezuma Slough Index, 0.8, was similar to previous indices measured in Montezuma Slough in the last 10 years (see Table X-13). In 1997, only two surveys were conducted because striped bass reached 38.1 mm in length early in the season. The Delta Index of 1.0 was marginally higher than that of the previous year. The Montezuma Slough index of 0.1 was lower than any indices measured in Montezuma Slough in the last 10 years. This decrease continued in 1998, when the Delta Index hit its lowest value to date, 0.1, and the Montezuma Index hit its second lowest value of 0.4 (Tables X-13 and X-14).

Table X-14. Results from the 1998 striped bass tow-net survey
(Since the abundance of striped bass was still increasing up to the third survey, only the last 3 surveys were used in the final index calculation.)

	Survey 1 7/1 - 7/4		**Survey 2 7/15 - 7/21**		**Survey 3 7/29 - 8/2**		**Survey 4 8/12 - 8/16**		**Survey 5 8/26 - 8/30**		**Final Index 8/30**
Area[a]	Catch	Index	Catch	Index	Catch	Index	Catch	Index	Catch	Index	
Montezuma Slough	275	3.4	280	2.4	191	1.8	72	0.9	41	0.4	0.4
Suisun Bay	23	0.7	93	4.2	130	4.9	128	4.2	26	1.0	0.9
Suisun Bay Subtotal	298	4.1	373	6.6	321	6.7	215	5.1	67	1.4	1.3
Sacramento River	1	0.0	4	0.2	8	0.3	6	0.3	0	0.0	0.0
Lower San Joaquin	3	0.2	6	0.5	26	0.6	14	0.6	1	0.0	0.0
East Delta	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0	0.0
South Delta	6	0.1	31	0.6	26	0.4	1	0.0	0	0.0	0.0
Delta Subtotal	10	0.3	42	1.3	17	1.3	21	0.9	2	0.1	0.1
Total[b]	308	4.5	439	7.8	106	8.0	237	5.9	69	1.5	1.4
Mean Lengths	23.1 mm		27.5 mm		22.3 mm		28.6 mm		37.1 mm		38.1 mm

[a] Area indices may not sum to equal the total indices, due to rounding of index values.
[b]Includes striped bass caught at Station 340 on the Napa River, which are not included in index calculations.

5. Conclusions

Since the decrease in striped bass young-of-the-year has been relatively constant over the last 30 years and has occurred in the Delta as well as in Suisun Marsh, it is unlikely that changes in Montezuma Slough abundance are related to installation and operation of the Suisun Marsh Salinity Control Gates. Researchers have monitored the decreases in striped bass in the estuary and note that the decline dates back to 1977 (SFEI 1997). Kimmerer and others (2000) reported that abundance of young-of-the-year striped bass is mainly a result of egg production and flow (represented by X_2). Their analysis indicates a decline in egg production since the late 1970's resulting from a decrease in the adult population of striped bass in the Sacramento-San Joaquin Estuary. The decline in the adult population appears to be a result of increasing adult mortality and episodic drops in abundance due to climate effects, such as El Nino events (Kimmerer and others 2000). In addition, Kimmerer and others (2000) reported that declining abundance of young-of-the-year to age 3 fish appear to be a result of a decline in carrying capacity in the Estuary.

The question proposed in the monitoring plan cannot be answered through this or any other monitoring program currently being implemented, since it is not possible to determine whether the SMSCG are having an impact on abundance without a control treatment. Further, available data suggests that abundance trends in the marsh are similar to those seen elsewhere in the Delta, regardless of gate operations and are likely the result of declining carrying capacity and a decline in adult striped bass.

6. Recommendations

DWR proposes to eliminate reporting to ACOE and BCDC on this element as a condition of permit compliance, but to continue the UC Davis Larval Sampling Program.

The striped bass tow-net survey provides critical information on the status of young-of-the-year striped bass in the Delta and Suisun Marsh. Analysis of these data can lead to a greater understanding of factors affecting striped bass abundance and help form the technical basis for regulatory decisions that aim to increase the abundances of this species. Likewise, data provided by the UC Davis Larval Fish Sampling Program on young-of-the-year striped bass abundance is critical in terms of the information it provides on long term trends in abundance.

Notes

Baxter, Randall. (California Department of Fish and Game, Stockton). August 19, 1998. Personal conversation with Eliza Sater.

Edwards, George. (California Department of Fish and Game). January 19, 1996. Personal conversation and fax transmission with Leslie Pierce.

Matern, Scott. (University of California, Davis). February 26, 2001. E-mail communication with Leslie Pierce.

Mecum, Lee. (California Department of Fish and Game). 1995.   Personal conversation with Eliza Sater.

Mecum, Lee. (California Department of Fish and Game). 1997. Personal conversation with Eliza Sater.

Moyle, Peter B. (University of California, Davis). April 11, 1998. E-mail communication with Eliza Sater.

Pierce, Mark. (US Fish and Wildlife Service). April 19, 1996. E-mail communication with Leslie Pierce.

Pierce, Mark. (US Fish and Wildlife Service). February 16, 2001. Personal conversation with Leslie Pierce.

Chapter XI
Pond Water Management

One objective of the monitoring program was to provide data to evaluate the effects of management on pond water SC, soil water SC, and vegetation. This chapter evaluates the relationship between various management practices, such as leaching and flooding, on pond and soil water SC. The effects on vegetation are examined in Chapter 7, Vegetation.

A. Influence of Pond Water Level on Soil Water Specific Conductance

The influence of pond water level on soil water SC was evaluated by examining soil water SC in response to pond stage recorder (PSR) activity. Soils were considered submerged or saturated when the PSR values were greater than zero. Values below zero were interpreted as pond water levels below pond bottom where soils were low in moisture or dry. Because of the great variability in edaphic and hydrologic characteristics among the soil tube sites on the same ownership, only the data collected at the soil tube closest to the PSR was considered.

The most obvious trend in soil water SC on the managed wetlands in relation to pond water level was an immediate decrease in soil water SC as ponds were flooded in the fall. This change occurred because the addition of water to dry soil lowered the concentration of solutes in the soil. There were 33 data sets that included flood-up and soil water SC records and of those, 24 (73%) showed a decrease in soil water SC after flood-up (21% increased and 6% did not change). Soil SC dropped quickly as water was diverted onto dry pond bottoms, decreasing SC by as much as 75% (West Family Club). This drop in soil SC as pond soils became saturated was observed on all ownerships in the monitoring program in almost every year.

As ponds were drained at the end of the water management season, soil water SC decreased at most sites. Of 64 complete data sets, soil water SC at 29 (45%) decreased as water level dropped, 23 (36%) did not change, and 12 (19%) increased.

Another prevailing trend was that soil water SC increased markedly after drainage was completed. Of 56 data sets that included both drainage and soil water SC records, 34 (61%) showed an increase in soil water SC after the ponds were drained (14% decreased and 25% showed no change). This increase was most likely due to an increase in salt concentration in the soil as water content decreases.

Similar, though shorter-term effects were seen with leaching. Leaching is a quick drain-flood-drain cycle. Soil water SC tended to decrease as drainage occurred, and continue to decrease (or stay stable) with rapid re-flooding. Ownerships that underwent leaching appeared to temporarily depress soil SC throughout the leaching period; however, soil SC usually increased to pre-leach levels after final drainage. Leaching may not actually "flush" salts from the soil profile as previously thought, but may aid in controlling soil SC because of an increase in slough-pond water exchange activity; soil pore space is drained of high SC water and replaced with lower SC water resulting in an overall lowering of soil water SC. Leaching may also function to maintain high soil moisture which helps keep salt concentrations low.

B. Effects of Flood Duration on Pond and Soil Water Salinity

Pond water and soil water SC averages were compared with flood duration to determine if a relationship was evident. The flood duration is the number of days that there is water above pond bottom.

No consistent relationship between flood duration and pond water SC was found. Three ownerships, Sprig, Mallard, and Gum Tree, had very stable flood durations throughout the monitoring period, but only Sprig had stable pond water SC from year to year. No consistent relationship between flood duration and pond water SC was seen for Grizzly Island, Grizzly King, and Morrow Island. Tule Belle, Joice Island, Island Club, Teal, and West Family had a loose inverse relationship between hydroperiod and SC. On these ownerships, as flood duration increased, pond water SC tended to decrease, and vice versa.

For all the monitored ownerships, it appeared that soil water SC was independent of flood duration. Because soil water SC usually increases during the months that a pond is dry, it was expected that soil water SC would increase as the flood duration decreased, but this did not consistently occur during the monitoring period.

When examining the data from just those sites with long (280+ days) or short (120 days or less) flood durations, there was no correlation between flood duration and pond water SC, soil water SC, or vegetation. The lack of correlation may be due to the variability in flood duration from year to year; it is likely that effects of flood duration cannot be seen after just one year of exposure, and there were no sites that consistently had very long or very short flood duration.

Based on the available hydroperiod data, it is difficult to draw any conclusions about the effect of hydroperiod on pond and soil water SC. It should be noted that the effect of hydroperiod on pond and soil water SC may be partially masked by the drought conditions occurring during the majority of the study period. Changes in hydroperiod may not cause significant enough effects in the pond water SC to overcome effects caused by the drought conditions. It does appear that hydroperiod has a greater effect on pond water than soil water, as several ownerships had a consistent relationship between flood duration and pond water, but there appeared to be no relationship with soil water SC.

C. Effects of Circulation on Pond and Soil Water Salinity

Circulation of channel water through the ponds is a component of active water management. The purpose of circulation is to keep the pond water from “stagnating” and increasing in SC. Pond water can increase in SC from factors such as evaporation and dissolution of salts in the soil. Circulation is accomplished by partially opening the fill and drain structures, which allows some water in at high tide and some out at low tide, while maintaining a fairly constant water level in the pond. Clubs may not circulate due to insufficient infrastructure or inactive management.

Although pond stage recorder information cannot be used to determine circulation patterns, circulation effectiveness can be indicated by the SC of water throughout the pond. When a pond is well circulated, the SC of the pond water should be fairly uniform throughout the pond at any given time. Thus, poorly circulated ponds will display more variation among monitoring sites than will well-circulated ponds.

Monthly pond water SC values were compared for the different sites at each monitored ownership. Mallard, Grizzly King, Tule Belle, and Gum Tree had the greatest variation among monitoring sites, indicating poor circulation in these ponds. Conversely, sites within a pond were almost always within 2 mS/cm of one another at Sprig, Teal, Grizzly Island pond 4A, Morrow Island, Island Club, and West Family. From the data collected, however, it does not appear that circulation had a measurable effect on soil water SC. Although most of the poorly circulated ponds showed steadily increasing soil water SC, and the well-circulated tended to have stable or fluctuating soil water SC, this was not universally true. There was no difference between well- and poorly-circulated ownerships in the range of average soil water SC over the monitoring period.

D. Effects of Leaching on Soil Water Salinity

Leaching is recommended to remove salts that accumulate in the soil as water evaporates during the summer months. A leach cycle is a rapid drain-flood cycle, and is most effective at reducing soil water SC if completed in 30 days or less. Ponds are drained to at least mudflat stage (no standing water in pond), but the best results are achieved if the water level in the ditches is brought down to 12 inches below the pond bottoms. Ideally, this is accomplished within 20 days. Once drainage is complete, the pond is immediately reflooded to a depth of 8 to 12 inches. This can usually be done in ten days or less. The leach cycle is then followed by final drainage, another leach cycle, or circulation. As with circulation, clubs may be unable to leach due to pond bottom elevation, insufficient infrastructure, or inactive management. Some ponds can only drain by gravity and cannot complete a leach cycle within the 30-day period.

1. Short-term effects of leaching

The pond stage records were used to determine if leach cycles were conducted. Of the twelve monitored ownerships, only six (Morrow, Tule Belle, Island, Grizzly King, Grizzly Island, and West Family) conducted leach cycles during three or more years of the monitoring program (Table XI-1).

Table XI-1. Summary of Club Leaching Patterns

Club	Years	# of Leaches
Morrow	1986, 1988, 1989, 1992 1987, 1990, 1991 1985	0 1 2
Tule Belle	1988, 1992-1995 1985, 1986, 1989-1991 1987	0 1 2
Teal	1985-1987, 1989-1992 1988	0 1
Joice Island	1988-1990	0
Island Club	1995 1985-1987, 1991, 1993 1988-1990, 1992, 1994	0 1 2
Gum Tree	1986, 1987, 1989-1992 1985, 1988	0 1
Grizzly King	1991 1985, 1987-1990, 1992 1986	0 1 2
Sprig	1986-1992 1985	0 1
Grizzly Island	1986, 1990 1987, 1988, 1992-1995 1989, 1991	0 1 2
Mallard	1985, 1987-1989, 1991, 1992 1986, 1990	0 1
West Family	1991 1992-1995	1 2
Goodyear	1993 1992, 1994, 1995	0 1

To assess the effects of leaching, soil water SC values from sites adjacent to pond stage recorders were examined. At 15 sites where a leach cycle took 30 days or less, soil SC never increased in the month following the leach cycle. Salinity stayed the same at three and decreased at least 1 mS/cm at 12, for an average SC decrease of 3.7 mS/cm.   At 19 sites where a leach cycle took 40 days or more, soil SC increased at 8, stayed the same at 4, and decreased at 7 for an average SC decrease of 1.2 mS/cm. The average soil SC change at all sites (leached and unleached) during these same time periods was a decrease of 1.4 mS/cm, indicating that a 30-day leach can result in a measurable decrease in soil water SC immediately afterwards. However, in the month following completion of the leach cycle, about half the leached sites had soil water SC equal to or greater than the SC before initiation of the leach.

2. Long-term effects of leaching

Clubs' leaching patterns were compared with soil water SC to determine if there is any long-term correlation. Because of the large degree of variability in soil water SC values between sites, between years, and between ownerships, it was not possible to determine the cause of long term changes in soil water SC. Several analyses were made, including (1) comparison of annual soil water SC averages for individual sites during years when leaching was done and not done; (2) comparison of long term trends in soil water SC for monitored ownerships that leached regularly and those that rarely leached; and (3) examination of soil water SC averages for each year to determine whether leached sites had lower SC than those sites that were not leached. None revealed consistent relationships between soil water SC and leaching. There were no consistent long term patterns between sites that were leached and those that were not. However, the majority of monitored ownerships with increasing soil water SC, Morrow, Tule Belle, Joice Island, Gum Tree, and Sprig, did not leach for most of the years of the monitoring program.

There was one exception to the inconsistent results of these analyses. West Family Club was the only ownership to conduct at least one leach cycle every year, and leaching was usually done to one-foot below the pond bottom, which is the recommended depth for maximum salt reduction. Soil water SC at this ownership was usually the lowest in the western marsh, and sometimes lower than many eastern marsh sites. It is apparent that annual leaching to a depth of one-foot can have a significant effect on soil water SC.

E. Importance and Consequences of Management

The data collected during the monitoring period indicate that the benefits of active water management on the managed wetlands are significant, as reflected in the soil water SC and vegetation diversity (see Chapter 6, Soil Water and Chapter 7, Vegetation). There are many components of management (water control structures and ditches, flood duration, circulation, and leaching) which may affect one or more components of the managed wetland such as pond water SC, soil water SC, and vegetation diversity. In addition, there are independent factors such as applied water SC, pond elevation, and soil type, which affect other conditions on the managed wetlands.

The effects of water management are clearly illustrated by a comparison of West Family Club (site 47) and Goodyear (site 48). There are many similarities between these two sites, and striking differences. These two monitored ownerships are located in the western marsh, flood from Goodyear Slough, and monitored sites were located in Reyes type soils. Pond water SC values were also quite similar, despite a few high values (Figure XI-1). These high values are either from first flood-up when the salts that have moved to the soil surface through evaporation are dissolving into the pond water, or from late in the season when the ponds are draining and salts are accumulating in the pond as water evaporates. The striking difference between the two ownerships is in water management, resulting in substantial differences in soil water SC and vegetation.

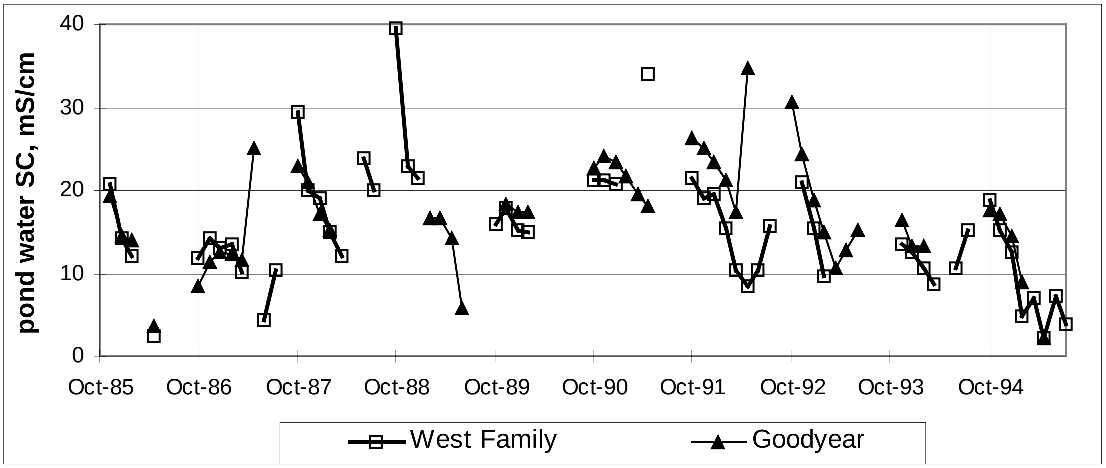

Figure XI-1. Pond water SC at West Family Site 47 and Goodyear Site 48, WY86-95.

Pond and soil water SC and vegetation were monitored at both clubs starting in water year 1986, but pond stage recorders were not installed until 1992. The management histories of the properties, however, are known. West Family Club was one of the most closely managed ponds in the marsh. West Family management included both late and early drawdown regimes, including annual leach cycles, in a successful effort to control soil water SC (Figure XI-2) and promote a diversity of wetland vegetation. Vegetation around site 47 was usually dominated by either fat hen or alkali bulrush (Figure XI-3).

When the monitoring program began in water year 1986, the Goodyear property was a privately owned club called Sprig Haven. In 1986 and 1987, the club was very successful at managing for fat hen. During surveys those years, almost all the surveyed points were fat hen (Figure XI-3). In 1988, DFG acquired the property as part of its Goodyear Management Unit, but active water management did not begin until the fall of 1989. During the year of “no management”, soil water SC increased from about 25 mS/cm to 50+ mS/cm (Figure XI-2), and the fat hen was almost completely replaced by pickleweed and bare ground. After 1989, water management rarely included leach cycles, and soil water SC stayed above 40 mS/cm, and the pond continued to be dominated by salt-tolerant pickleweed (Figure XI-3).

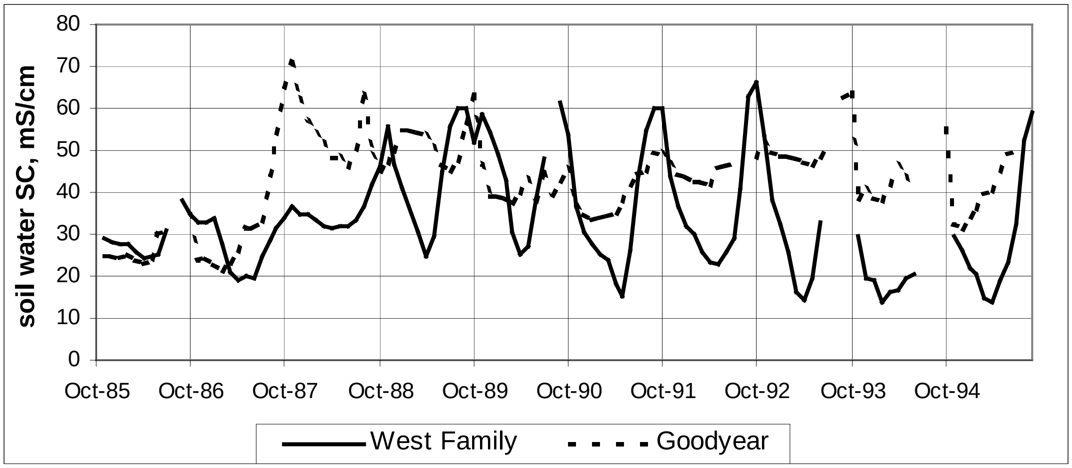

Figure XI-2. Soil water SC at West Family Site 47 and Goodyear Site 48, WY86-95.

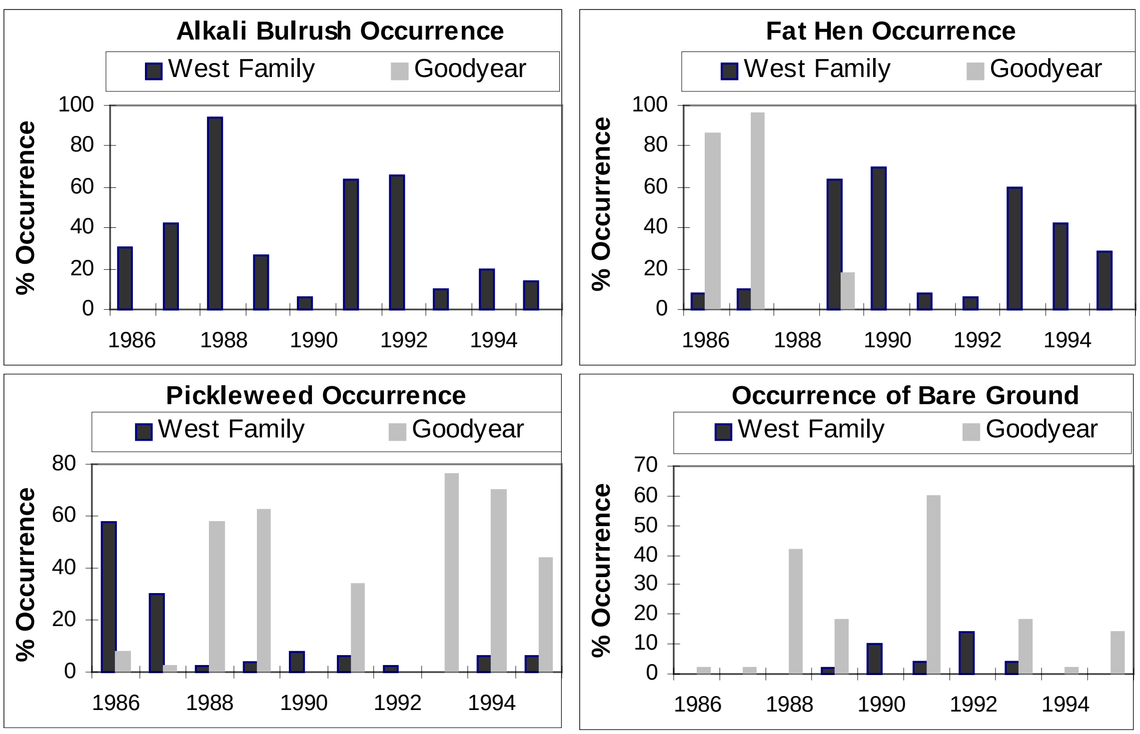

Figure XI-3. Occurrence of wetland plants along transects at Goodyear Site 48 and West Family Site 47, WY86-95.

F. Conclusions

The following conclusions can be drawn from the data collected by the monitoring program:

- Sites located near water control structures and circulation ditches are likely to have lower pond and soil water SC than more distant sites.
- Soil water SC usually increases when ponds dry in the summer. Soil water SC usually decreases in the fall when the ponds are flooded.
- Leaching usually decreases soil water SC for about one month.
- Annual leaching to one foot beneath the pond bottom can decrease soil water SC or prevent increases during times of drought.
- Changes in soil water SC and vegetation cannot always be related to water management, applied water SC, or other physical factors measured by the monitoring program.
- Despite a 6-year drought, water managers were able to provide habitat for waterfowl, and when appropriate management techniques were used, grew waterfowl food plants recommended by Mall (1969).

G. Recommendations

Future monitoring of the managed wetlands should include the following:

- Active record-keeping by water managers. Ideally, all management actions would be recorded by date and objective, including opening or closing water control structures, circulation, leaching, discing, burning, and ditch creation or maintenance.
- Place more soil monitoring sites in each pond, and collect data on a daily or weekly basis, so that changes in SC can be related to management events.
- Collect pond water samples daily or weekly to assess effects of water management actions (like circulation) on pond water SC.
- Monitor vegetation throughout the pond so that changes vegetation can be related to changes in water management and soil water SC.
- Conduct tests on moist-soil management (maintain water in ditches to keep the pond bottom moist in the summer) to see if this management could keep soil water SC low, maintain wetland vegetation, and provide wildlife habitat without some of the soil chemistry problems that are often associated with traditional diked wetland management.

Chapter XII
Other Monitoring and Regulatory Activities

This section includes brief discussions of Suisun Marsh monitoring activities which were outside the study period for this comprehensive review, or were required by permits or agreements other than the SMPA or Monitoring Agreement. The results of the monitoring are not included in this report but most are available in annual DWR reports entitled Suisun Marsh Monitoring Program Data Summary: 19## Water Year. Results not found in the annual data summaries are cited below.

A. Vegetation Monitoring

Conservation measures outlined in the USFWS 1981 Biological Opinion required that marsh-wide vegetation monitoring be conducted by DFG. A monitoring plan was developed to assess the overall vegetative composition of the Marsh utilizing color aerial photography in conjunction with ground verification every third year (Triennial Survey). The results would be compared to those from past flights and reported in acres and percent of total vegetation for each major plant species. The surveys and analyses were completed in 1981, 1988, 1991, and 1994.

In addition to monitoring vegetation change across the marsh, the Triennial Survey was supposed to monitor the acreage of preferred salt marsh harvest mouse habitat. To assist in this, the marsh was divided into five zones to decrease the potential for significant local decreases in habitat to be masked by increases in other areas of the marsh. These zones were established prior to the 1981 survey, and were used in the analysis of vegetation changes in each subsequent survey.

Although the aerial surveys were completed, the aerial photo interpretation and annual vegetation monitoring were not implemented. The five zones established in the marsh were not used for their original purpose of assessing changes in preferred salt marsh harvest mouse habitat. There were concerns about the methodology used and the lack of useful maps from the 1988, 1991, and 1994 surveys. Determination of individual species composition marsh-wide would require an extremely intensive sampling effort with rigorous replication to report data at the species level with any degree of certainty. On the ground, marsh habitats are mixed assemblages of several species rather than monotypic stands. To lump percentages of species within each habitat into single species categories loses the character of the actual habitat.

The triennial vegetation survey scheduled for water year 1997 was postponed in order to update the objectives and methodology. In 1998 aerial photos were taken for use in a pilot study to develop an new survey methodology. A vegetation survey was conducted in 1999 under the direction of Dr. Todd Keeler-Wolf at DFG. The survey methodology was designed to meet the goal of documenting changes in preferred habitat for the SMHM, as well as gather the vegetation information in such a way that it can be used for a variety of other purposes, including correlating management activities with vegetation changes; gathering data to support the use of a GIS format that will allow queries, and overlaying of additional information such as soil type and hydrology, and a creation of a base map for future studies.

The vegetation mapping methodology used reflected the protocol for “Field Methods for Vegetation Mapping” supported by the National Park Service and Biological Resources Division of the US Geological Survey (USGS 1997). One benefit of this approach is the creation of a precise map with detailed vegetation classifications. The specific methods of this monitoring plan are described in The Triennial Survey for the Suisun Marsh Proposal for a New Methodology (DFG 1999).

Sensitive Plant Species

There are several sensitive plant species within the Suisun Marsh. Those listed under the federal or State Endangered Species Acts are discussed below.

Soft bird’s-beak, *Cordylanthus mollis* ssp. *mollis* is listed as a federal Endangered and State Rare species. Soft bird’s-beak is found in the upper peripheral halophyte zone of relict undiked tidal marshes. This annual species is most commonly associated with pickleweed (*Salicornia virginica*), and often parasitizes its roots.

Intensive floristic surveys of undiked tidal marshes throughout Suisun Marsh were conducted by DWR biologists during 1992 and 1993. The DFG Joice island Unit northeast of the Joice Island bridge, and the Rush Ranch property were also searched in 1991. Three populations of soft bird’s-beak were located. Until 1997, annual, casual surveys of these populations were done by a DWR biologist. These populations were last visited and found extant in 1998.

Suisun thistle, *Cirsium hydrophilum* var. *hydrophilum,* is listed as a federal Endangered species. It is an erect, many-branched thistle about 3-4 feet tall. Only two populations are known from tidal marshes of Suisun Marsh. (DWR 1994c).

Mason’s lilaeopsis, *Lilaeopsis masonii,* is listed as Rare under the California Endangered Species Act. It is a low-growing herbaceous perennial that appears grass-like. It is most common on actively eroding slough banks, wave-cut beaches, and on rotting wood such as pilings or emergent snags.

Masons lilaeopsis was detected during vegetation surveys of limited areas of Suisun Marsh during 1991 and 1993. An intensive marsh-wide survey specifically for Mason’s lilaeopsis was conducted in 1992. These surveys located the species throughout most regions of the marsh.

B. Wildlife Surveys

1. Waterfowl

Waterfowl Food Habits Study. In 1996, DWR and USBR agreed to fund a 2-year cooperative field study of the feeding ecology of waterfowl in the Suisun Marsh, sponsored by SRCD, DFG, USGS Biological Resources Division, and the University of California at Davis. The purpose of the study was to identify foods consumed by northern pintails, mallards, and green-winged teal relative to foods available in early fall and early winter in the Suisun Marsh.

Data from past food habit studies conducted in the marsh were obtained from gizzard analyses, which have been discredited because they bias results in favor of hard seeds at the expense of softer foods. Lack of accurate feeding ecology information is critical because wetland management in the Marsh, which is predicated upon detailed management plans, continues to be based on early food habit study results based on gizzard analyses. The proposed study will use techniques that do not contribute to bias based on the hardness of food items consumed or on the statistics used.

Actively feeding birds were observed and collected from September through January during 1997/98 and 1998/99. Data were obtained from: 1) shooting actively feeding ducks, 2) pass-shooting birds flying between night feeding areas and diurnal roosts, and 3) collecting esophagi from hunter-shot ducks on duck clubs and state wildlife areas. In addition, five soil cores and five water samples were taken at each collection site immediately after the ducks were shot and processed. This will provide samples of vegetation and food items present at the feeding site for comparison with foods actually consumed. Processing of the esophageal contents began in 1998. A final report is expected by March 2000.

2. SMHM Surveys

Results of 1995-1998 monitoring are included in Chapter IX, Salt Marsh Harvest Mouse Surveys.

3. Other sensitive species

The following information is taken from the Summary of Sensitive Plant and Wildlife Resources in Suisun Marsh During Water Years 1984 – 1994 (DWR 1994c). Results of surveys and locations of sensitive species can be found in that document and are not listed here.

The **California clapper rail** (*Rallus longirostris obsoletus*) is listed as an endangered species under both the State and federal endangered species acts. These chicken-sized birds are secretive, nonmigratory residents of undiked tidal salt and brackish marshes.

Breeding season censuses for presence of California clapper rails were conducted throughout the undiked tidal marshes of Suisun Marsh in 1991, 1992, 1993, and 1994 by DWR and DFG personnel. The primary objective was to survey all areas of potential habitat rather than to obtain accurate population estimates. California clapper rails were detected during each survey.

The **California black rail** (*Laterallus jamaicensis coturniculus*) was listed as threatened by DFG in 1985, and is a federal Special Concern species. This small bird is the most elusive North American rail, spending most of its life in rodent tunnels under dense marsh vegetation.

Surveys by DFG and DWR have detected California black rails during breeding season surveys in 1991, 1992, 1993, and 1994. The rails have also been detected during winter census', indicating year-round presence in Suisun Marsh.

C. Aquatic Species Monitoring

Results of 1995-1999 monitoring are included in Chapter X, Aquatic Resources.

D. Management

1. Updated Management Plans

In the late 1970s, the Soil Conservation Service prepared management plans for each of the 158 privately managed wetlands in the Suisun Marsh. DFG also prepared management plans for State-owned land in the marsh, which follow similar management regimes and schedules as the private properties. These management plans have not been modified or updated since they were written nearly 20 years ago, and no longer reflect the current environmental, regulatory, or physical constraints that occur in the Suisun Marsh managed wetlands.

At the time these management plans were written, they presented the most recent scientific information available to provide water management schedules, with the intent to produce waterfowl food plants and leach soil salts from the root zone (Rollins 1981). These plans recommended effectively leaching soil salts from the root zone by removing water from the upper foot of the soil profile. This is accomplished by performing leach cycles; rapidly flooding and draining the wetlands to one-foot below pond bottom for one or more cycles. These water management schedules recommended rigid timing of water application, drainage, and water levels within the ponds.

The water management schedules written by Rollins were intended to promote the growth of specific waterfowl food plants. The goal of the late drawdown schedule was to maximize production of alkali bulrush and minimize production of tules, cattails, saltgrass *(Distichlis spicata),* and pickleweed *(Salicornia virginica).* The late drawdown schedule requires the following water management actions:

- the wetlands are drained after January to a depth of at least one foot below the pond bottom
- pond then reflooded to the 8-12 inch water level
- pond is drained immediately to one foot below pond bottom
- pond is reflooded to a 4-6 inch depth
- drained to mudflat
- reflooded to about 6 inch depth and water is then circulated in April and May to facilitate the seed-set cycle of alkali bulrush
- pond is completely drained in June

The early drawdown schedule targeted fat hen while suppressing tules, cattails, and saltgrass growth. The early drawdown schedule requires the following water management actions:

- ponds are leached once to a depth of at least 1-foot below pond bottom following the end of January
- pond is reflooded to 8-12-inch depth
- ponds are drained completely by mid-March

The studies by George and Mall focused on the gizzard contents of waterfowl to determine plant seed preference. While the results of these studies were widely accepted as accurate at the time, the current thought among waterfowl researchers is that gizzard content analysis studies present questionable results, because hard seeds are the primary substance found in gizzard contents. Foods such as invertebrates, soft seeds, and vegetative matter are difficult or impossible to identify in the gizzard. The gizzard analyses may have overlooked other valuable waterfowl food resources found in the Suisun Marsh. As a result, a new food habits study evaluating waterfowl esophageal contents instead of gizzard contents was initiated in the fall of 1997. This study was designed and will be conducted by the U.S. Biological Survey, the University of California at Davis, and SRCD. Results will update information on waterfowl food preferences of three seed-eating species. The results and information obtained from this two-year study will be incorporated into the new Individual Ownership Adaptive Management Habitat Plans, which will replace the outdated management plans. As more up-to-date information becomes available, the new Individual Ownership Adaptive Habitat Management Plans can be modified to incorporate this information.

The outdated management plans and water management schedules were based upon the goal of single species management to produce the maximum production of waterfowl seed crops. The new adaptive management plans will provide landowners scientific information and present multiple management options with the goal of producing a diverse mosaic of vegetation within the managed wetlands. This management goal will be met by: (1) maintaining soil water salinity levels within the natural salinity ranges characteristic of brackish marsh soils as outlined by the USDA Soil Conservation Service (1977); (2) considering the habitat needs of resident and migratory waterfowl as well as those of other wildlife including threatened and endangered species; and (3) making management decisions based on annual environmental factors, physical constraints, and regulatory restrictions.

The past management plans were concerned mainly with establishing monocultures of plant species considered attractive to waterfowl. The new Individual Ownership Adaptive Management Habitat Plans will consider a multitude of factors on a year to year basis, to produce a diversity of wetland vegetation. The formation of the plan for each property will take into account recent scientific information, a hydrologic computer model of each property, adaptive management goals, landowner and water manager participation, and the following list of considerations:

- Physical Management Constraints:
  - Wetlands soil types and natural salinities
  - Water control facilities: Gate size, location, elevation, pipe invert
  - Pond bottom elevation
  - Pond bottom topography
  - Ditch capacity, size, depth, vegetative obstructions

- Environmental Constraints:
  - Water year type
  - Applied water SC
  - Climatic conditions, temperature, rain fall, seasonal variability
  - Pond water levels
  - Tidal variation at diversion and drainage points
  - Geographic location in relation to SC gradients

- Endangered Species Considerations:
  - Endangered species habitat protection
  - Endangered species habitat management goals
  - Endangered species fisheries protection through water diversion restrictions

2. Red Water Study

The term "red water" is used to describe the results of a complex chemical reaction that can occur in managed brackish marshes like Suisun Marsh. The repeated draining and flooding of diked, brackish wetlands results in a chemical reaction that produces soils containing a basic ferric sulfate and sulfuric acid called cat's clay (Neely 1958). In simple terms, the reaction proceeds in this manner:

- Brackish or salt water containing sulfates inundates soils with high organic content. Under anaerobic (flooded) conditions, the sulfates react with the organic material and are reduced to sulfides.
- The sulfides react with iron in clay soils to produce iron sulfide.
- When the ponds are drained, the action of aerobic bacteria produce sulfuric acid as a waste product and oxidize sulfides to sulfates.
- When ponds are re-flooded, the sulfuric acid in the wet soil dissolves iron, which moves with the acid to the soil surface and into the pond water.
- This iron/acid mixture reacts with alkaline ($pH>8$) pond water to form red ferric hydroxide flocculate which colors the water red. In addition the pH of the soil may drop to as low as 2.5, which can create acidic conditions in the pond water.

There is evidence of acid-water problems in Suisun Marsh. Paul Crapuchettes owned and managed a duck club in western Suisun Marsh from 1968 through 1996. Under his intensive management the club consistently had low soil water salinity and diverse wetland vegetation. However, he experienced acid soil problems such as red water, acidic soil and pond water pH, loss of vegetation, and significant decrease in duck use, which he attributes to his water management techniques (Crapuchettes 1999).

In 1995, an agreement was made between SRCD, DWR, USBR, DFG, the National Biological Service (now the Biological Resources Division of the U.S. Geological Survey) and the California Waterfowl Association to fund a study evaluating the extent, duration, distribution, and quality of acid/red water, and its effect on waterfowl usage in Suisun Marsh. The study was conducted during the winters of 1995-96 and 1996-97 and, through aerial surveys, monitored the use of orange/red-hued water by wintering waterfowl in the Suisun Marsh. In addition to waterfowl use, the water chemistry (pH, specific conductance) and physical characteristics (surface area, depth, secchi disk reading, color) of orange/red-hued water and non-orange/red water in the Marsh were measured (USGS *et al* 1999a, 1999b).

Also examined was the response of captive mallards and pintails to various water types to determine if red color, acidity, or both, deter waterfowl use. Captive birds were exposed to red-colored acid water, clear-colored acid water, enhanced-red neutral water (color enhanced with food dyes), and clear-colored neutral water (control). Each experiment contrasted individual duck use of the experimental water and the control (USGS *et al* 1999b).

Pooled across both years of the aerial survey, 1995-96 and 1996-97, the density of dabbling ducks was higher in red-colored water (2.68 ducks/ha) than in nonred-colored water (0.78 ducks/ha, $P<0.001$). Duck use was also higher in ponds that had lower secchi readings (more turbid) and were more shallow than ponds not used by ducks, however specific conductivity and pH were similar between used and nonused ponds (USGS *et al* 1999a).

The captive bird study found that both mallards and pintails significantly preferred clear-colored acid water to the control water. There was a tendency for ducks to prefer neutral water to red-colored acid water when food was present in the water, but water treatment effects were strongly influenced by individual duck differences or tub preferences, and the effects were inconsistent. No other significant preferences were detected (USGS *et al* 1999b).

3. SRCD Alkali Bulrush Study

From March to July 1996, SRCD conducted a study to measure the effects of leaching on soil water SC and alkali bulrush growth (SRCD 1997). Eight study sites on privately owned diked wetlands were used.   To assess the effect of ditches on soil water SC, four of the sites were in ponds with V-ditches and 4 in ponds without V-ditches. Soil samples (12” soil cores) were taken before and after leaching, and were divided into three 4” increments (0-4”, 4-8”, and 8-12”).   At each soil sample site, the number and height of alkali bulrush shoots within a 1 m quadrat were recorded.

This study found that soil water SC did not decrease significantly after leaching. Soil water SC in ponds with V-ditches were only slightly lower than those measured in ponds without V-ditches. Both types of ponds had a significantly greater number of alkali bulrush shoots after leaching, however there were no measurements at control sites, so it is not known whether this difference was attributable to leaching. Ponds with V-ditches had more alkali bulrush shoots both before and after leaching. It was speculated that this may be a result of more active management. Height of shoots was higher in ditched ponds, and increased in both types of ponds after leaching.

Chapter XIII
Conclusions

A. A Review of Requirements of the Suisun Marsh Preservation Agreement

Article 4 of the SMPA, Review of Operations, requires the following:

(1) Review the effectiveness of the facilities constructed pursuant to the SMPA
(2) Assess the relationships among water SC, soil water SC, and plant SC tolerance
(3) Determine if objectives of the SMPA are being achieved and if any adjustments are needed

The objectives of the SMPA are:

- To assure that USBR and DWR maintain a dependable water supply of adequate quantity and quality within the marsh to mitigate the adverse effects of the CVP and SWP and a portion of the adverse effects of other upstream diversions;
- To improve marsh wildlife habitat to the extent compatible with other CVP and SWP purposes;
- To define the scope of the obligations of USBR and DWR to provide the water supply, distribution, redistribution and management facilities necessary to accomplish the first two objectives; and
- To assure that USBR and DWR recognize that the water users in the marsh have been and will continue to divert water for wildlife habitat management.

Article 5 of the SMPA, Monitoring, requires “DWR and DFG to monitor and report on surface water and soil water qualities, water elevations, marsh vegetation and wildlife species in accordance with the…Monitoring Agreement...”

B. A Review of Requirements of the Monitoring Agreement

The Monitoring Agreement Article 9, Review, requires the parties to “…review the Agreement and identify any modifications appropriate for accomplishing its objectives.” The objectives of the Agreement are “…to describe a methodology…to carry out an appropriate monitoring program to meet the objectives of the SMPA.”

The monitoring program outlined in the Monitoring Agreement is included as Appendix A. In brief, the following monitoring is required:

- Channel Water Quality. The EC at the control stations will be monitored with continuous recorders
- Diversion and Drain Water Quality. A point on each monitored ownership shall be monitored continuously for EC.

- Standing Surface Water. The EC of standing surface water at each soil water salinity sampling site shall be determined monthly.
- Water Level. Maintain a continuous recorder to measure water elevation on each monitored ownership. At each control station maintain a continuous water elevation recorder for five years.
- Soil Water Salinity. Soil water salinity will be measured monthly at 40 to 50 sites on monitored ownerships.
- Plant Survey. The species composition of vegetation on lands within 35 meters of each soil water monitoring site will be determined in August or September of each year.
- Seed Production. The seed production of alkali bulrush and fat hen within 35 meters of each soil water monitoring site will be determined each year.
- Marsh-Wide Plant Survey. The overall vegetative composition of the marsh shall be determined every third year.
- Waterfowl. The species and number of waterfowl in the marsh will be determined by aerial surveys from September through January of each year.
- Salt Marsh Harvest Mouse. If the marsh-wide plant survey identifies a significant change in preferred habitat and if the parties determine that surveys are necessary, surveys of the population of the mouse will be promptly arranged.
- Striped bass and *Neomysis.* Conduct studies of the annual abundance of young striped bass and *Neomysis* in Montezuma Slough.
- Effects of SMSCG Operations on Fish. Conduct studies to determine the impact of predators and disruption of fish associated with the SMSCG.

C. SMPA Requirement 1: Review the effectiveness of the facilities

1. Effectiveness of the Initial Facilities

The Roaring River Distribution System (RRDS), the Morrow Island Distribution System (MIDS) and the Goodyear Slough Outfall were constructed between 1979 and 1981 and are collectively known as the Initial Facilities. The goal of operation of the Initial Facilities was to provide wetland managers with lower salinity water with which to flood their ponds. With respect to physical parameters (channel water salinity, hydraulics, or capacity) the effectiveness of these three facilities cannot be quantitatively addressed, as there was neither pre-project nor post-project monitoring of these parameters.

The construction of RRDS increased the capacity, installed fish screens, and provided turnouts to 14 private ownerships and DFG. Prior to RRDS construction, many of these ownerships flooded with water from Grizzly Bay, and the turnouts and increased capacity of RRDS gave them access to the lower salinity water of Montezuma Slough. The operation of this facility has been satisfactory to DWR, DFG and the affected landowners and can be considered to have met the objectives for which it was constructed.

The construction of MIDS allowed landowners to divert Goodyear Slough water through two channels into the easternmost area of Morrow Island, and drain into Grizzly Bay or

Suisun Slough. Prior to MIDS construction, landowners drained back into Goodyear Slough, resulting in the re-introduction of high salinity drainage water into the slough. Evaluating whether MIDS has met its objectives has been problematic, with some disagreement between DWR and adjacent landowners about the proper use and effectiveness of the system. However, following system dredging and levee work in 1997, the landowners appeared to be more satisfied with the operation of this facility.

Goodyear Slough Outfall was constructed to open up the dead-end of Goodyear Slough with the objective of increasing circulation and reducing salinity in Goodyear Slough. Unfortunately, there is no pre-project data on Goodyear Slough salinity or hydrology to use in assessing the effect of the Outfall on those conditions.

2. Effects of SMSCG Operations on Channel Water Specific Conductance

The effectiveness of Suisun Marsh Salinity Control Gates (SMSCG) operation on SC at marsh monitoring stations was analyzed using field data and hydrodynamic modeling. Field SC data were used to determine the mean and range of SC response for Suisun Marsh monitoring stations given initiation or termination of SMSCG operation. Seventy-three-year computer model simulations with and without SMSCG operation were used to estimate the percentage of time Suisun Marsh SC standards may be exceeded.

a. Analysis of Suisun Marsh Specific Conductance Data During SMSCG Operation Tests

The objective of this analysis was to determine the influence of gate operation (initiation or termination) on monitoring station SC based on SC data collected at Suisun Marsh monitoring stations during SMSCG operation testing. The SC data was collected during SMSCG operation tests conducted in 1989 and 1991 (Vayder 1989, Brown 1991). The gate operation tests include three periods of “full-bore” gate operations with stop-logs installed, and one period with no gate operation and stop-logs removed.

Hourly near-surface SC data from six monitoring stations within Suisun Marsh were used for the analysis. The monitoring stations were: S64 on Montezuma Slough at National Steel, S49 on Montezuma Slough at Beldon’s Landing, S54 on Montezuma Slough at Hunter Cut, S42 on Suisun Slough at Volanti Slough, S21 at Sunrise Club on Chadbourne Slough, and S35 on Goodyear Slough at Morrow Island (Figure I-7).

The goal of the analysis was to determine the relative influence of SMSCG operations and hydrologic conditions on SC at monitoring sites within Suisun Marsh. SC changes due to hydrology were estimated using Chipps Island and Collinsville SC along with historical tidally-averaged outflow from the Sacramento-San Joaquin Delta. The analysis was conducted by visually inspecting time-series plots of monitoring station SC and hydrology indicators during the month after SMSCG operation was either initiated or terminated. Analysis priority was given to periods when hydrologic indicators were relatively constant. The apparent change in SC due to a SMSCG operation change (initiate or terminate “full bore’ gate operations) was noted for each monitoring station. The results are summarized in Table XIII-1. Under each operation category (initiate or terminate), the mean change in channel water SC is shown along with the observed range of SC responses. Table XIII-1 shows only those changes apparently caused by SMSCG operation. These analyses show that SC decreases after initiation of full bore SMSCG operation and increases after termination of SMSCG operations.

Details of the 1988-89 and 1989-90 tests of SMSCG operations can be found in two DWR memos to Walter G. Pettit, Chief of the Division of Water Rights, SWRCB (Vayder 1989, Brown 1991).

Table XIII-1. influence of Suisun Marsh Salinity Control Gate operation on Suisun Marsh monitoring station SC.

STATION	Initiate full-Bore Gate Operation		Terminate Gate Operation	
	Mean change	Range	Mean change	Range
S64	-8	0: -10	+4	+2: +5
S49	-6	-5: -8	+6	+5: +7
S54	-4	+2: -5	+3	+2: +4
S42	-3	-2: -4	+4	+4
S21	-2	-2: -3	+3	+3
S35	-1	-1: 0	+2	+2: -1

From DWR 1998.

b. Analysis of 73-Year Computer Model Results

The objective of the hydrodynamic analysis was to determine the percentage of time Suisun Marsh SC standards would be exceeded based on computer model simulations of 73 years of data with and without SMSCG operation.

The Delta Simulation Model 1 (Suisun Marsh Version) was used for the analysis. The input data for the simulation were monthly average Delta inflows and water project exports from the statewide planning model DWRSIM. Based on a constant level of future water demand and historical (1922-1994) monthly average unimpaired reservoir inflows, DWRSIM simulated State Water Project operations given water user demands and operational and environmental constraints. The monthly average 73-year hydrology used for this analysis was based on DWRSIM operation study 1995C6F-SWRCB-469 which conforms to 1995 Water Quality Control Plan requirements.

To directly simulate the impact of the SMSCG on channel water SC, two 73-year simulations were conducted based on the same hydrology, one without SMSCG operation, and one with SMSCG operation. The without gate operation scenario was run first and the monthly progressive daily mean high tide SC was recorded. Based on these results, and assuming that the SMSCG would only be operated between October and May when required to meet standards, a 73 year schedule for SMSCG operation was determined. Using this schedule of gate operations, the same 73 year hydrology was run and the progressive daily mean high tide SC recorded.

Modeling results were summarized using “Area-Frequency Analysis” to show the frequency and extent that monitoring station SC standards would be exceeded with and without SMSCG operation. For both scenarios, the progressive daily mean high tide SC output for the October through May period between 1922 and 1994 was compared with the SC standard for each monitoring station and the difference recorded. Differences were ranked and a percentage frequency was calculated for each value. Plotting the ranked differences versus the frequency provides an estimate of the amount of time SC standards would be exceeded under each scenario. Results of the comparison of the area frequency plots of the with- and without-gate operation scenarios are listed below:

- Without SMSCG operation, standards were exceeded more often, and by a larger magnitude than with SMSCG operation.
- Only station C2 near Collinsville always met standards under both scenarios.
- Without SMSCG operation, the frequency of standard exceedence was approximately 25% at S64 (near National Steel), 37% at S49 (Beldon’s Landing), 30% at S42 (Volanti Slough), 30% at S21 (Sunrise Club), 21% at S35 (Goodyear Slough) and 40% at S97 (Cordelia Slough at Ibis Club).
- With SMSCG operation, the frequency of standard exceedence was approximately 18% at S35, and 30% at S97. The standards were not exceeded at other monitoring stations.
- At stations where standards were exceeded under both scenarios (S35 and S97), the magnitude of exceedence was less with SMSCG operation.

D. SMPA Requirement 2: Assess relationships among channel water SC, soil water SC, and plant SC tolerance

The data collected by the monitoring program were not adequate to quantitatively address these relationships. Under some conditions, a direct relationship was found between channel and pond water SC, but this was affected by water management activities and on-site conditions, which were not measured or controlled. Examination of long term soil water SC showed that it was affected by channel water SC, but there appeared to be no direct, or short term (one year) relationship.

The occurrence of plant species around the soil monitoring sites could not be linked to soil water SC. The data suggest that alkali bulrush decreases in abundance when soil water SC is greater than 25 mS/cm, but this was not always the case. As with soil water SC, there were too many unmeasured and uncontrolled variables affecting vegetation to make any conclusions about the effects of channel or soil water SC.

E. SMPA Requirement 3: Determine if SMPA objectives are being achieved and if any adjustments are needed

USBR and DWR have acted in good faith to meet all four of the SMPA objectives.

1. First SMPA objective: To assure that USBR and DWR maintain a dependable water supply of adequate quantity and quality within the marsh to mitigate the adverse effects of the CVP and SWP and a portion of the adverse effects of other upstream diversions.

A dependable water supply in this case refers to the ability of DWR and USBR to supply water of adequate quality to protect the beneficial uses of Suisun Marsh. To compensate for the effects of upstream diversions and to assure that adequate water quality is maintained, the State Water Resources Control Board implemented Decision 1485 which established SC standards to maintain Suisun Marsh as a brackish water marsh capable of producing high-quality food and habitat conditions for waterfowl and other wildlife. With just a few minor exceptions, DWR and USSR have consistently been in compliance with SC standards in the Suisun Marsh.

In addition to meeting the SC standards, several facilities have been constructed in Suisun Marsh to make lower SC water available to the landowners. These facilities are discussed above and in Chapter I.

2. Second SMPA objective: To improve marsh wildlife habitat to the extent compatible with other CVP and SWP purposes.

The primary purpose of the water quality standards and the physical facilities is to provide the landowners with water of adequate SC so that they can provide conditions favorable to the growth of plants that Mall (1969) found to be important waterfowl food plants. The monitoring program (see Chapter 11) found that despite a 6-year drought, water managers have been able to provide habitat for waterfowl, and when appropriate management techniques are used, grow waterfowl food plants recommended by Mall (1969).

Other actions taken to improve wildlife habitat were only those mandated by permits or agreements including:

- Management by DFG, on behalf of DWR, of 1,078 acres of land specifically for the endangered salt marsh harvest mouse.
- Numerous studies (see Chapter 10) have been conducted on fish species in the marsh. These studies have examined habitat conditions, fish populations, and effects of the SMSCG on fish.

3. Third SMPA objective: To define the scope of the obligations of USBR and DWR to provide the water supply, distribution, redistribution and management facilities necessary to accomplish the first two objectives.

The SMPA parties agreed that DWR would have the primary responsibility for activities and compliance in the marsh, but that USBR would provide 40% of the funds for activities required by the SMPA and Monitoring Agreement.

4. Fourth SMPA objective: To assure that USBR and DWR recognize that the water users in the marsh have been and will continue to divert water for wildlife habitat management.

Under the SMPA, wetland managers have maintained the ability to divert water to manage their properties in Suisun Marsh. One aspect of the SMPA, the Individual Ownership Cost-Share Program, has encouraged landowners to improve management facilities by reimbursing the private landowners 75% of the cost of flood and drain facilities identified as "needed improvements" in their Individual Ownership Management Plans. DWR and USBR have reimbursed landowners approximately 1.2 million dollars under this program. Under the Original SMPA, there was only a 50% cost share reimbursement offered to the landowners. However, the SMPA parties amended the Agreement in 1992 to offer a 75% reimbursement to encourage participation in the program.

The proposed Amendment Three to the Suisun Marsh Preservation Agreement includes funding of an additional $2 million for the Managed Wetland Improvement Fund. Under this program, wetland managers will continue to be reimbursed 75% for improvements to flood and drain facilities identified as "needed improvements" in their management plans and will be eligible for 50% reimbursement for other activities to improve management capabilities on their property.

The ability of wetland managers to continue to divert water has become more of a regulatory issue in recent years. To protect winter-run Chinook salmon and delta smelt, water diversions through unscreened structures were restricted in SRCD's Regional General Maintenance Permit issued by the US Army Corps of Engineers in March 1995. For the protection of winter-run, the permit specifies gate closures for unscreened diversions from February 21 through March 31. Also, water intake structures shall be closed to reduce the effective area of the opening to the greatest extent possible and still meet the needs for circulating water from November 1 through the end of waterfowl season. Delta smelt restrictions are based on water year type. Water diversions from tidal sloughs are restricted after April 1 of each year to a two-week window during all water years except the first wet or above normal water year.

Diversions equipped with fish screens are not restricted in the marsh. DWR and USBR have installed and/or provided funding for installation of fish screens to allow for the continued diversion of water by wetland managers. DWR and USBR also installed a fish screen on the Roaring River Distribution System, and in 1997, the actuators on the intake pipes were automated to allow for the greatest diversion to RRDS while meeting the USFWS criteria for protection of delta smelt.

DWR and USBR funded the installation of the Lower Joice Island Fish Screen, which was required as a condition of installation of this facility in 1992. Once testing of this screen is complete, ownership of the screen will be transferred to the landowner. DWR and USBR also funded the Grizzly Island Fish Screen which was installed in 1995. This screen allows for unrestricted diversions on DFG managed wetlands on the Grizzly Island Wildlife Area.

5. Review for Needed Adjustments to SMPA

The SMPA has been amended twice, and currently a Draft Amendment Three is being negotiated. The first amendment was signed in 1988 and resulted in changes in the location of the S21 monitoring station and the construction schedule for the Cygnus and Lower Joice island facilities. The second amendment was signed in 1994 and increased the reimbursement for participation in the Individual Ownership Cost Share Program.

In July 1995, a DFG, DWR, USBR, and SRCD Negotiation Team convened to begin updating the SMPA based on changed conditions in Suisun Marsh. The changes in conditions include: (1) the effectiveness of the Suisun Marsh Salinity Control Gates at controlling SC, and (2) increased outflows provided under the 1994 Principles of Agreement and the SWRCB's 1995 Water Quality Control Plan. The Negotiation Team agreed that additional large scale facilities for the control of SC in the marsh are no longer necessary, and that SMPA objectives could be met through programs to assist landowners in managing their properties. For details of Amendment Three, see the "Draft Environmental Assessment and Initial Study for Amendment Three to the Suisun Marsh Preservation Agreement" (DFG et al 1998). The specific actions in Amendment Three include:

- Make channel water SC standards consistent with the 1995 Water Quality Control Plan.
- Convert S35 and S97 from compliance to monitoring stations.
- Establish a Managed Wetlands Improvement Fund.
- Establish a Drought Response Fund.
- Establish criteria to operate the SMSCG in September, and operate and maintain existing facilities.
- Fund updates to the Individual Ownership Management Plans.
- Fund a Water Manager Program.
- Fund a Joint-Use Facilities Program.
- Establish a Portable Pumps Program for diversions and drainage.

D. Evaluation of Monitoring Program Limitations

1. Tide and Channel Water SC Monitoring

From a regulatory standpoint, monitoring the SC and stage of the water in Suisun Marsh channels is the most important aspect of the monitoring program. It has been very successful as the data are accurate and are collected in "real" time.

2. On-Site Monitoring

The on-site monitoring data were found to be inappropriate to address the stated objectives due to problems with the collection of data in the field, and with the methods outlined in the Monitoring Agreement. These data limitations are discussed in the data analyses in chapters II through XI.

The primary limitation of the monitoring program was the design of the on-site portion of the program. The objective of the Monitoring Agreement was to "…carry out an appropriate monitoring program to meet the objectives of the SMPA." The Monitoring Agreement details what specific monitoring will be done, but does not indicate how the individual components will be assembled to determine if the objective was met. In addition, the SMPA Article 4 "Review of Operations" states that "…information on the relationships among water salinity, soil water salinity, and plant salinity tolerance gained from the marsh monitoring program shall be considered…" However, the Monitoring Agreement does not include methods for assessing these relationships.

Ideally, the basic steps in setting up a monitoring program are: (1) pose a discrete research objective, (2) determine what data are needed and how they will be analyzed, including what statistical tests will be conducted, and (3) develop a monitoring program to meet the stated objectives and provide the necessary data.

Unfortunately, the on-site monitoring plan did not follow these steps. First of all, the research objective was too broad to be quantified without development of a series of more specific questions which would have allowed the monitoring to be more focused. As it was, the question was so broad, and there were so many uncontrolled factors operating, that it was impossible to obtain an answer. In addition, the Monitoring Agreement did not specifically address the question of assessing the relationships among water salinity, soil water salinity, and plant salinity tolerance. Secondly, there was no detailed plan for how the collected data would be used to answer the research question. Finally, there was no evaluation of the necessary quantity and quality of data needed to answer the research objective, or the statistical tests to be used to analyze the data.

D. Other Conclusions and Findings of the Monitoring Program

In addition to addressing the specific requirements of the SMPA and Monitoring Agreement, other results and relationships were indicated by the monitoring program data. A summation of the results of the monitoring program are addressed in greater detail in the preceding chapters, and are briefly listed below:

1. Pond Water SC

- Pond water SC tends to be directly related to channel water SC, but there can be a lag of several months or a year in pond water SC response to changes in channel water SC.
- Pond water SC values are most often about 5-10 mS/cm greater than that of the applied water.

- Water management actions affect pond water SC values, and may mask effects of applied water SC.

2. Soil Water SC

- Soil water SC was not found to be directly related to applied water SC.
- Soil water SC values tended to increase during the 1987-1992 drought (higher applied water SC values) and decrease with wet conditions (lower applied water SC values).
- Soil water SC appeared to be more closely related to applied water SC during the fall flood-up period, than to applied water SC during the rest of the year.
- The data suggest that soil water SC is affected by location relative to water control structures such as intakes and circulation ditches. Sites near these structures tended to have lower soil water SC than more distant sites.

3. Vegetation

- The data from the on-site monitoring program indicate that from 1985 to 1992, pickleweed occurrence increased and alkali bulrush occurrence decreased at the monitoring sites.
- There did not appear to be any direct relationship between changes in soil water SC and changes in vegetation occurrence.
- Pickleweed stands are resistant to changes in soil water SC, and can persist for several years in lower-than-optimal soil water SC.
- Alkali bulrush occurrence tends to be very low when soil water SC is greater than 25 mS/cm for most of the year.
- There did not appear to be any direct relationship between production of alkali bulrush seed or fat hen biomass and flood duration or soil water SC.

4. Water management

- Water management activities can have a significant effect on soil water SC.
- Soil water SC decreased when ponds were flooded, and increased when ponds were drained.
- Leaching to one foot below pond bottom can reduce soil water SC for the short term (one or two months).
- Pond and soil water SC appeared to be independent of flood duration.
- Consistent utilization of water management activities such as circulation and leaching can prevent significant increases in soil water SC and can contribute to abundance and diversity of vegetation. Conversely, failure to utilize circulation and leaching can lead to increasing soil water SC and increases in a few species of salt tolerant plants and patches of bare ground.

Chapter XIV
Recommendations for Future Monitoring

A. Adjustments to Existing Monitoring

The specifics of monitoring methods have been addressed in preceding chapters. This chapter will focus primarily on monitoring needed to fulfill the objectives of the SMPA and Monitoring Agreement. The last section will discuss monitoring or research that would provide important information on Suisun Marsh, but is beyond the purview of existing agreements.

1. Channel Water SC Monitoring

The current methodology for channel water SC data is appropriate for meeting the requirements of the Plan of Protection, SMPA, 1995 Water Quality Plan, and regulatory permits. The addition of a SC monitoring station in the northeastern marsh would provide information on a portion of the marsh where the hydrology has not been monitored. Monitoring information from this area would provide important information on effects of tidal movements and creek flows on local channel water SC.

2. On-site monitoring of pond water SC, soil water SC, and vegetation

The objectives of the on-site monitoring were to assess the effects of: (1) channel water SC on pond water SC, (2) channel water SC on soil water SC, (3) pond water SC on soil water SC, (4) soil water SC on vegetation occurrence, and (5) soil water SC on seed production.

(1) The data collected during the monitoring program were sufficient to assess the relationship between channel and pond SC, although it was determined that management factors such as circulation and ditching also affect this relationship. Since the monitoring achieved the stated goal, further monitoring of this relationship is not needed.

(2) and (3) The monitoring program data were not able to consistently confirm the relationship between soil water SC and channel water SC or pond water SC. Although both soil water and channel water SC increased during the 1987-1992 drought, indicating that soil water SC is related to channel water SC, this relationship was not always apparent over the short term. Because the relationship between channel and soil water SC can be readily altered by management actions, further monitoring would require close controls to assess the correlations between numerous factors (such as water year type, time of flood-up, circulation, duration of flooding, configuration of ditches, leaching). Such monitoring would be time- and labor-intensive, and because management is highly variable with water year type and management goals, such research would probably not provide much useful information to wetland managers in the marsh.

(4) Increasing soil water SC is a serious concern of wetland managers in the Suisun Marsh. The results of the monitoring program show that despite a 6-year drought, soil

water SC on monitored ownerships did not increase to levels lethal to wetland vegetation. It appears that the Suisun Marsh channel water SC standards, which were imposed to mitigate the effects of the State Water Project and Central Valley Project, do insure that wetland managers can continue to grow wetland plants and provide habitat for wintering waterfowl. The limited vegetation data collected indicate that salt-tolerant plant species did increase during the drought, but incidences of bare ground did not increase significantly.

The on-site monitoring program was unable to quantify the relationship between soil water SC and vegetation, partly because of the complicating effects of wetland management actions such as time of flood-up, circulation, duration of flooding, configuration of ditches, and leaching. The monitoring program substantiated the results of Rollins (1981), which showed that spring leach cycles can control increases in soil water SC. However, during the eleven years of the monitoring program, monitored ownerships employed leaching less than half the time. Since it is difficult to quantify the relationship between soil water SC and wetland vegetation in managed wetlands, and because leaching is a known remedy for increasing soil water SC, any further studies of these relationships would need to be carefully tailored to answer very specific management questions rather than addressing general conditions throughout the marsh.

(5) The on-site monitoring program was not able to substantiate Mall’s (1969) study which found a strong correlation between alkali bulrush seed production and soil water SC in May and length of flood duration. The D-1485 Suisun Marsh channel water salinity standards were established to maximize alkali bulrush seed production, and were considered “adequate for marsh protection only if efficient marsh management practices were employed” (Rollins 1981). Because the results of the monitoring were inconclusive, they cannot be used to determine whether inconsistent seed production is due to inadequacy of the standards, marsh management practices, or other factors.

A new food habits study is currently being done (Miller, 1997). The study conducted in 1960-1961 (George 1965), by using gizzard data, may have underrepresented the occurrence of soft foods in the waterfowl diet. The new study examines esophageal contents, and should provide more accurate data on what mallards, pintails, and green-winged teal are eating in Suisun Marsh. Results of this study are expected in 2001.

Further research on waterfowl food production in Suisun Marsh should not be undertaken until the results of the current feeding ecology study are finalized. This study may reveal that alkali bulrush, fat hen, and brass buttons are not as important as once believed, and wetland managers may want new management schemes to increase production of other plant (or invertebrate) species. In addition any future monitoring of management actions should include waterfowl surveys and provide data to assess other waterfowl success criteria such as cover, and resting and loafing habitat.

3. Waterfowl Surveys
The on-site monitoring in the marsh neglected to study the desired goal of most marsh activities: waterfowl. The monitoring program looked at channel water salinity, pond and soil water salinity, and vegetation occurrence and production in the managed wetlands. However, it is impossible to draw any relationships between these factors and waterfowl use because no data were collected on waterfowl numbers within the monitored ownerships. For example, many management and regulatory actions have promoted conditions favorable to alkali bulrush, but there are no data to show that ponds with high levels of alkali bulrush seed production attract and hold large numbers of waterfowl.

All future monitoring on management actions in the marsh should include waterfowl surveys so that the true success of those actions can be assessed.

4. Salt Marsh Harvest Mouse Monitoring
A new SMHM monitoring proposal was developed in June 1999 for monitoring the SMHM on conservation areas within the marsh. The objectives of the project include: 1) determining if SMHM inhabit conservation areas, 2) assessing the condition of SMHM habitat on conservation areas, 3) determining relationship between vegetation and SMHM presence/absence, and 4) assessing abundance by comparing results over time. It would be valuable to add a component for monitoring SMHM use of lands managed as waterfowl habitat so that the effects of management actions can be assessed, rather than assumed.

The SMHM monitoring can be used as a tool to assess, in part, the success of mitigation measures in the marsh. The surveys will provide information on the success of SMHM habitat management in the mitigation areas, and will be used to modify management techniques where necessary.

There are a number of genetic questions raised by results of the monitoring. Using standard morphological characteristics and measurements, some harvest mice cannot be named as either salt marsh harvest mice or the similar, non-endangered, western harvest mice. A genetics study is needed to develop genetic footprints for each species and to tie these genetic characteristics to morphological characteristics. A genetics study could also determine if there is hybridization between the two species, and if there are significant differences between isolated populations of SMHM within Suisun Marsh. In 2000 Dr. Francis Villablanca at Cal Poly San Luis Obispo submitted a contract to DWR for such a genetics study. DFG and DWR, during 1999 and 2000, collected hair samples from captured harvest mice to provide genetic material for the study. The study is expected to take two years to complete.

5. Aquatic Resources Monitoring
- Adult salmon passage studies at SMSCG should continue until SMSCG Steering Group determines that passage levels have improved.
- SMSCG Steering Group should review and address juvenile salmon predation impacts at the SMSCG.

- The UC Davis Suisun Marsh Fish Sampling and Larval Survey programs should continue.
- DWR will stop reporting on striped bass egg and larval survey, striped bass tow-net survey, and zooplankton and N. mercedis survey.

B. Application of existing monitoring programs to Suisun Marsh Preservation Agreement Amendment 3 actions

This section will provide a discussion of the potential application of existing monitoring to specific actions in Amendment 3.

1.   Vegetation Survey of the Suisun Marsh

As discussed in Chapter XII a new vegetation survey methodology was developed by DFG for implementation in the 1999 Suisun Marsh Vegetation survey. This new methodology will incorporate data from aerial photographs, satellite images, and field vegetation surveys into a geographic information system to create an accurate vegetation map of the marsh.

a. Article VI. Mitigation

Amendment 3, Article VI states that "USBR, DWR, and DFG shall provide wetlands mitigation specified in the Suisun Marsh Mitigation Agreement…The mitigation will provide multispecies habitat…". The vegetation survey will provide an accurate representation of vegetation types, and acreages of each, throughout the marsh, including a delineation of SMHM habitats and acreages. The method allows for an adaptive approach to repeat mapping, which allows for efficient re-mapping of the marsh. This will allow for accurate change detection in vegetation types and habitats from year to year. Thus, the vegetation survey will provide a tool to assess whether mitigation measures are providing habitat for various listed and sensitive species in the marsh.

b. Article VII. Funds for Managed Wetland Improvements and Drought Response

The purpose of the Drought Response Fund as detailed in Article VII is to compensate landowners for the costs of more intensive management required during periods of drought. The hope is that more intensive management will compensate for higher salinity water and prevent any degradation of wildlife habitat. The vegetation survey data may be useful in assessing the success of the program. Use of the GIS format will allow annual overlaying of vegetation types with applied water quality. This will provide information on changes in vegetation types during the drought period and applied water quality. However, it must be noted that acquisition of detailed management data would be critical to evaluating the success of the program.

c. Article VIIB. Water Manager Program

Through the Water Manager Program SRCD will employ staff to help coordinate and improve water management practices on Individual Ownerships throughout the marsh. Objectives of the program include: improving habitat and water management, improving flooding and leaching abilities on managed wetlands, and recommending habitat improvements and water management techniques. The vegetation survey data will provide a means to track changes in vegetation types and habitats annually. Correlating management practices with vegetation changes over time should provide one mechanism to assess the success of the management practices.

2. Channel Water Quality Monitoring

The Suisun Marsh monitoring program collects channel water EC and tide stage data at selected sites throughout the marsh. EC and tide stage data are collected continuously at 15-minute intervals.

a. Article VII. Funds for Managed Wetland Improvements and Drought Response

Channel water EC data can be used to provide representative applied water EC for various managed wetlands. These data can be used in conjunction with the management and vegetation survey data to help assess the success of the Drought Response program.

b. Article VIIB. Water Manager Program

As with the Drought Response program, channel water EC data can provide representative applied water EC data for use in evaluating the success of management practices implemented through the Water Manager program.

C. Monitoring that may be beyond the purview of the SMPA and Monitoring Agreement

The following is a list of Suisun Marsh monitoring that may support the objectives of the SMPA, Suisun Marsh Monitoring Agreement, and other regulatory conditions, but are not mentioned specifically in existing agreements. More detailed monitoring recommendations have been made by a number of multi-agency groups considering ecological issues and monitoring in the San Francisco Bay-Delta Region, including CalFed, Bay Area Wetland Ecosystem Goals Project, and the Suisun Ecological Workgroup.

Water Quality

- Monitor the effects of wetland management on channel water quality, such as effects of drain water on dissolved oxygen levels
- Additional monitoring stations in areas near tidal wetlands such as Hill Slough, Peytonia Slough, and Rush Ranch/Cutoff Slough
- Sample for contaminants and assess their effects on the ecosystem

Managed Wetlands

- Study the occurrence of acid soils in the managed wetlands
- Assess the feasibility of diked wetland management that would more closely mimic tidal wetland and provide waterfowl hunting opportunities
- Determine if moist soil management could improve soil water salinity and wetland habitats in the diked wetlands

- Monitor the long-term effects of different waterfowl management practices (moist soil management, leaching cycles, different flood durations) on marsh soils and vegetation
- Use long-term controlled studies to reevaluate the relationship between soil water SC and wetland vegetation
- The May 1995 Water Quality Control Plan recommended that "DWR, USBR, DFG, and SRCD should conduct a study to determine the relationship between channel water SC and soil water SC under alternative management practices, including an assessment of whether the current channel water SC objectives are needed to support the beneficial uses and whether different water quality objectives, including soil water SC objectives, would provide equivalent or better protection for the beneficial uses if favorable management practices are also used."

Tidal Wetlands

- Studies to determine the spatial and temporal variability of tidal wetland plant communities, and assess the effects of duration of flooding, soil salinity, soil redox potential, soil pH and channel water salinity.
- Study the effects of tidal marsh on sediment budgets, tidal prism, and nutrient supplies
- Study the efficacy of tidal marsh restoration projects, including formation of channels, availability of sediment, evolution of tidal marsh features, optimal patch size, filtration of sediments and toxics, effects on local flooding, establishment of plant and animal communities—with focus on sensitive species

Vegetation

- Assess the impacts of invasive non-native plant species on sensitive tidal wetland plant species
- Regular surveys of listed and sensitive plant species
- Surveys to track expansion of invasive exotic plant species

Aquatic Resources

- Expanded studies on the impacts of SMSCG operation on aquatic resources and tidal wetlands
- Examine the relationship between X2 and the distribution and abundance of aquatic species in the marsh
- Study impacts of invasive nonnative species such as zebra mussels and Chinese mitten crabs
- Determine the extent and use of shallow water habitats and tidal marshes by aquatic species, especially native fish, and assess the feasibility of reshaping existing levees to create shallow water habitat
- Assess the effects of nonnative invasive species on aquatic resources
- Survey for zooplankton to assess distribution and abundance

Wildlife

- Expand the Feeding Ecology Study to include waterfowl species other than mallards, pintails, and green-winged teal
- Determine the relationship between waterfowl brood survival and channel water salinity
- Reinitiate clapper rail surveys to assess distribution of the species. Also conduct studies of clapper rail habitat distribution, food availability, reproductive success, juvenile and adult dispersal, movement between marshes, and sustainability of the population
- Conduct comprehensive surveys to determine distribution and relative abundance of wildlife species in tidal and managed wetlands
- Identification of potential keystone species that may serve as management targets for marsh ecosystem sustainability and diversity

Salt Marsh Harvest Mouse

Results of the SMHM monitoring have raised numerous questions about the mouse and it's use of habitats. These questions include:

- How do management actions in the waterfowl ponds affect SMHM?
- Can the ponds managed for waterfowl also sustain populations of SMHM?
- SMHM have been found in non-pickleweed habitats. Are they resident in these habitats, and are the populations sustainable there?
- What are the characteristics of "good" SMHM habitat in Suisun Marsh?
- Is there adequate habitat in the marsh to sustain SMHM populations?
- Are there adequate corridors between habitats of sustainable populations?
- Are population levels different in tidal and managed wetlands, as indicated by past surveys?

Chapter XV
References

Adams P. 1990. Saltmarsh Ecology. Cambridge University Press. 461 pp.

Adams P, Marshall S and Breck JE. 1990. Bioenergetics in Schreck, Carl B. and Peter B. Moyle ed. Methods for Fish Biology. American Fisheries Society. Bethesda, Maryland.

Alpine AE, Cloern JE. 1992. Trophic dynamic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnol Oceanogr 37(5):946–55.

Arnold A. 1996. Suisun Marsh History. Monterey Pacific Publ. Co. 253 pp.

Arthur JF, Ball MD. 1978. Entrapment of suspended materials in the San Francisco Bay-Delta estuary. U.S. Bureau of Reclamation, Mid-Pacific Region Technical Report. Sacramento (CA): U.S. Bureau of Reclamation. 106 p.

Briden L and Wernette F. 1993. 1992 Suisun Marsh Alkali Bulrush, Fat Hen and Plant Survey. Department of Fish and Game, Bay-Delta and Special Water Projects Division, Stockton.

Brown R. March 22, 1991. memo to Walter G. Pettit, Chief of the Division of Water Rights, SWRCB titled “Effectiveness of the Suisun Marsh Salinity Control Gates”. From Chief of Environmental Services Office, California Department of Water Resources. Located at Environmental Services Office, Sacramento CA.

[DFG] California Department of Fish and Game. 1988. File Memo “Salt marsh harvest mouse trappin in Suisun Marsh complex. Located at: 3251 S Street, Sacramento, CA, 95816.

________. 1989. Grizzly Island Wildlife Area Management Plan. 251 pp. + appendices.

________. 1994. Predator sampling near the salinity control structure site in Montezuma Slough, May 1993. Stockton (CA): California Department of Fish and Game. 33 pp.

________.1999. The Vegetation Survey for the Suisun Marsh Proposal for a New Methodology, Draft Report. 8pp. + appendices.

California Department of Fish and Game, US Bureau of Reclamation, California Department of Water Resources, Suisun Resource Conservation District. 1998. Draft Environmental Assessment and Initial Study for Amendment Three to the Suisun Marsh Preservation Agreement. Dept. of Water Resources. Sacramento, CA. 97pp + appendices.

[DPW] California Department of Public Works. 1931a. Bulletin No. 28, Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers. Division of Water Resources. 154 pp. + appendices.

________. 1931b. Bulletin No. 27, Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay. Division of Water Resources. 243 pp. + appendices

[DWR] California Department of Water Resources. 1984. Plan of Protection for the Suisun Marsh Including Environmental Impact Report. 176 pp. + appendices.

________. 1993. Suisun Marsh Monitoring Program Data Summary: 1992 Water Year. 38 pp. + appendices. Environmental Services Office.

_________. 1994a. Estimate of Salinity Changes in Suisun Marsh for Water Years 1987-1992 with CUWA/AG Criteria, Environmental Services Office. January 1994.

_________. 1994b. Summary of Salinity Changes in Suisun Marsh During Water Years 1984-1992, Environmental Services Office. November 1994.

_________. 1994c. Summary of Sensitive Plant and Wildlife Resources in Suisun Marsh During Water Years 1984-1994. 107pp. Environmental Services Office. December 1994.

________. 1995a. Suisun Marsh Monitoring Program Data Summary: 1993 Water Year. 58 pp. + appendices. Environmental Services Office.

________. 1995b. Channel Salinity Conditions in Suisun Marsh during Water Year 1993. Environmental Services Office.

________. 1995c. Suisun Marsh Salinity Control Gates fisheries monitoring. 1993 annual report. Sacramento (CA): California Department of Water Resources. 38 p.

________. 1996. Suisun Marsh Monitoring Program Data Summary: 1994 Water Year. 60 pp. + appendices. Environmental Services Office.

________. 1997a. Suisun Marsh Salinity Control Gates fisheries monitoring. 1994 annual report. Sacramento (CA): California Department of Water Resources. 53 p.

________. 1997b. Suisun Marsh Salinity Control Gates fisheries monitoring. 1995 annual report. Sacramento (CA): California Department of Water Resources. 59 p.

________. 1997c. Adult chinook salmon passage mitigation report. Sacramento (CA): California Department of Water Resources. 42 p.

________. 1997d. Suisun Marsh 73-year model study in support of SWRCB draft EIR for implementing the Water Quality Control Plan of the San Francisco-Sacramento-San Joaquin Delta Estuary. Appendix C. Sacramento (CA): California Department of Water Resources.

_________. 1998. Demonstration Document: Suisun Marsh Preservation Agreement Amendment Three Actions as a Means to Provide Equivalent or Better Protection than Channel Water Salinity Standards at Suisun Marsh Stations S-35 and S-97. 55 pps. + appendices.

_______. 1999. Suisun Marsh Salinity Control Gates annual fisheries monitoring report for 1997. Sacramento (CA): California Department of Water Resources. 66 p.

California Department of Water Resources, California Department of Fish and Game, and U.S. Bureau of Reclamation. 1987a. Suisun Marsh Mitigation Agreement. March 2, 1987.

_________. 1987b. Suisun Marsh Monitoring Agreement. March 2, 1987.

Crapuchettes PW. 1999. The limitation on active management in the Suisun Marsh. Draft. Available from DWR, Environmental Services Office, Sacramento, CA.

[CUWA] California Urban Water Agencies. 1994. Evaluation of potential effects of the proposed EPA salinity standard on the biological resources of the San Francisco Bay/Sacramento-San Joaquin Estuary [draft]. Sacramento (CA): R2 Resource Consultants, Inc. Reference Number 5. 65 p plus appendices.

Edwards GW, Fujimura RW. 1998. Final quality assurance project plan for the 1998 evaluation of the modification of the Suisun Marsh Salinity Control Gates on adult fall-run chinook salmon passage. Stockton (CA): California Department of Fish and Game. 27 p + appendices.

Edwards GW, Urquhart K, Tillman T. 1996. Adult salmon migration monitoring, Suisun Marsh Salinity Control Gates, September-November 1994. Interagency Ecological Program for the San Francisco Bay-Delta Estuary Technical Report 50. 27 p.

Evans RA and Love RM. 1957. The Step-Point Method of Sampling - A Practical Tool in Range Research. Jour. Rng. Mgmt. pp. 208-212.

Foss SF, Miller LW. 1996. Summer tow-net survey: 1995 young-of-the-year striped bass index. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. IEP Newsletter 9(3):11-15.

George HA, Anderson W, and McKinnie H. 1965. An Evaluation of the Suisun Marsh as a Waterfowl Area. Calif. Depart. of Fish and Game Administrative Report. 59 pp.

Goals Project. 1999. Baylands Ecosystem Habitat Goals: a report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U.S. Environmental Protection Agency, San Francisco, CA and S.F Bay Regional Water Quality Control Board, Oakland, CA.

Herbold B, Jassby AD, Moyle PB. 1992. San Francisco Estuary Project status and trends report on aquatic resources in the San Francisco Estuary. Prepared by University of California, Davis, for the San Francisco Estuary Project, U.S. Environmental Protection Agency. 257 p + appendices.

Heubach W. 1969. *Neomysis awatschensis* in the Sacramento-San Joaquin River Estuary. Limnol Oceanogr 14(4):533–46.

Hill MO. 1979. TWINSPAN: a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Section of ecology and systematics, Cornell University, Ithaca. New York.

[IESP] Interagency Ecological Study Program for Sacramento-San Joaquin River Estuary. 1987. Factors affecting striped bass abundance in the Sacramento-San Joaquin River System. Technical Report 20. Sacramento (CA): California Department of Water Resources. 149 p.

Jassby AD, Kimmerer W, Monismith SG, Armor C, Cloern JE, Powell TM, Schubel JR, Vendlinski TJ. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272–89.

Jones and Stokes Associates, Inc. and EDAW, Inc. 1975. Fish and Wildlife Element to the Suisun Marsh Protection Plan. Prepared for California Department of Fish and Game. 412 pp.

Kimmerer WJ, Cowan JH Jr., Miller LW, Rose KA. 2000. Analysis of an estuarine striped bass (*Morone saxatilis*) population: influence of density-dependent mortality between metamorphosis and recruitment. Can J Fish Aquat Sci 57:478–86.

Mall RE. 1969. Soil-Water-Plant Relationships of Waterfowl Food Plants in the Suisun Marsh of California. California Department of Fish and Game, Wildlife Bulletin No. 1.

Matern S, Meng L, Moyle PB. 1995. Trends in fish populations of Suisun Marsh, January 1994-December 1994. Annual report for Contract B-59636. Sacramento (CA): California Department of Water Resources. 36 p.

________. 1996. Trends in Fish Populations of Suisun Marsh, January 1995-December 1995. Annual report for Contract B-59998. Sacramento (CA): California Department of Water Resources. 41 p.

________. 1997. Trends in fish populations of Suisun Marsh, January 1996-December 1996. Annual report for Contract B-80900. Sacramento (CA): California Department of Water Resources. 52 p.

________. 1999. Trends in fish populations of Suisun Marsh, January 1996-December 1996. Annual report for Contract 94-6036494 B-81568. Sacramento (CA): California Department of Water Resources. 53 p.

Meng L, and Moyle PB. 1993. Abundance and Distribution of Native and Introduced Fishes of Suisun Marsh. Annual Report for Contract B-58854. Department of Water Resources. Sacramento, California. 32 pp.

Miller AW, Miller RS, Cohen HC, and Schultze RF. 1975. Suisun Marsh Study, Solano County, California. U.S. Department of Agriculture, Soil Conservation Service. 186 pp.

Miller MR. 1987. Fall and winter foods of northern pintails in the Sacramento Valley, California. J. Wildl. Manage. 51:405-414.

Monismith S. 1998. X2 Workshop notes. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. IEP Newsletter 11(4):6-14.

Moyle PB. 1976. Inland fishes of California. Berkeley (CA): University of California Press. 405 p.

Moyle PB, Herbold B. 1983. A survey of the fishes of Suisun Marsh: five-year progress report. Department of Wildlife and Fisheries Biology, University of California, Davis. 10 p.

________. 1986. Patterns in the distribution and abundance of Suisun Marsh fishes: 1979-1986. Department of Wildlife and Fisheries Biology, University of California, Davis.

Monroe MW, and Kelly J. 1992. San Francisco Estuary Project State of the Estuary: A Report on Conditions and Problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Prepared under Cooperative Agreement CE-009486-02 with the U.S. Environmental Protection Agency. 270 pp.

[NMFS] National Marine Fisheries Service. 994. Endangered Species Act Section 7 Consultation - Biological Opinion for Periodic Maintenance Activities Primarily for Private Waterfowl Clubs in Suisun Marsh. p.12.

[NOAA] National Oceanic and Atmospheric Administration. 1995. Climatography of the United States No. 81. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling; Degree Days 1961-1990. U.S. Department of Commerce. Asheville, NC.

Neely WW. 1958. Irreversible drainage – a new factor in waterfowl management. North Am. Wildl. Conf. 23:342-348.

Obrebski S, Orsi JJ, Kimmerer W. 1992. Long-term trends in zooplankton distribution and abundance in the Sacramento-San Joaquin Estuary. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary Technical Report 32. 42 pp.

Orsi JJ, Mecum LW. 1994. Decline of the opossum shrimp, *Neomysis mercedis*. IEP Newsletter Autumn 1994:10-11.

Orsi JJ. 1997. *Neomysis*/zooplankton abundance. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. IEP Newsletter 10(2): 20-21.

Orsi, JJ. 1995. Food habits of several abundant zooplankton species in the Sacramento-San Joaquin Estuary. Technical Report 41. Interagency Ecological Program for the Sacramento-San Joaquin Estuary.

Peterson H. 1997. *Potamocorbula amurensis*. Interagency Ecological Program for the Sacramento-San Joaquin Estuary. IEP Newsletter 10(2):24.

Pickard A, Baracco A, Kano R. 1982. Occurrence, abundance, and size of fish at the Roaring River Slough intake, Suisun Marsh, California during the 1980-81 and 1981-82 diversion seasons. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 3.

Raquel P. 1988. Striped bass egg and larval monitoring near the Montezuma Slough Salinity Control Structure, 1987. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 16. 7 p.

________. 1988. Predator sampling near the proposed salinity control structure site in Montezuma Slough, 1987. Stockton (CA): California Department of Fish and Game. 7 p.

________. 1989. Predator sampling near the salinity control structure site in Montezuma Slough, 1988. Stockton (CA): California Department of Fish and Game. 11 p.

________. 1990. Predator sampling near the salinity control structure site in Montezuma Slough, 1989. Stockton (CA): California Department of Fish and Game. 15 p.

________. 1991. Predator sampling near the salinity control structure site in Montezuma

Slough, 1990. Stockton (CA): California Department of Fish and Game. 16 p.

________. 1992. Predator sampling near the salinity control structure site in Montezuma Slough, 1991. Stockton (CA): California Department of Fish and Game. 24 p.

Rollins GL. 1973. Relationships Between Soil Salinity and the Salinity of Applied Water in the Suisun Marsh of California. California Department of Fish and Game 59(1):5-35.

_________. 1981. A Guide to Waterfowl Habitat Management in Suisun Marsh. California Department of Fish and Game. 109 pp.

[SFBCDC] San Francisco Bay Conservation and Development Commission. 1991a. Permit No. 35-78(M) issued March 13, 1979, as amended through June 24, 1997

_________. 1991b. Permit No. 4-84(M) issued June 26, 1984, as amended through June 25, 1991.

Schroeter RE, Moyle PB. 2000. Trends in fish populations in Suisun Marsh, January 1999-December 1999. Annual report for Contract B-81933. Sacramento (CA): Department of Water Resources.

[SFBAWEGP] San Francisco Bay Area Wetland Ecosystem Goals Project. September 1997. Draft species narratives for fish and macroinvertebrates [unpublished draft].

[SFEI] San Francisco Estuary Institute. 1997. State of the estuary: 1992-1997: vital statistics, new science, environmental management. Oakland (CA): San Francisco Estuary Project. 64 p.

Shellhammer HS. 1984. Identification of salt marsh harvest mice, *Reithrodontomys raviventris*, in the field and with cranial characteristics. *Calif. Fish and Game* 70(2):113-120.

SMSCG Technical Team. 2001. Findings of the Suisun Marsh Salinity Control Gate Steering Group Technical Team. Available from: http://www.iep.ca.gov/suisun/curr-report/currrep.html via the Internet. Accessed 2001 Feb 23.

Sokal RR, Rohlf FJ. 1995. Biometry: the principles and practice of statistics in biological Research. New York (NY): W.H. Freeman & Co.

Spaar SA. 1988. Suisun Marsh Salinity Control Gate Pre-project Fishery Resource Evaluation. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Technical Report 17. 52 p.

_________. 1992. Suisun Marsh Salinity Control Gates, Fishery Related Studies, 1992 Annual Report. Department of Water Resources. 44 p.

[SRCD] Suisun Resource Conservation District. 1996. The relationship between soil salinity and soil pH and alkali bulrush in the Suisun Marsh, CA. Suisun CA. 25 pp + appendices.

[SWRCB] State Water Resources Control Board. 1978a. Water Quality Control Plan, Sacramento-San Joaquin Delta and Suisun Marsh. Sacramento, California. 177 pp.

_________. 1978b. Water Right Decision 1485, Sacramento-San Joaquin Delta and Suisun Marsh. Sacramento, California. 44 pp.

_________. 1995. Water Quality Control Plan for the Sacramento-San Joaquin Delta Estuary. Sacramento, California. 45 pp.

_________. 1999. Final Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan. 3 volumes.

Stoner EA. 1937. A record of twenty-five years of wildfowl shooting on the Suisun Marsh, California. The Condor 39:242-248.

Swanson GA, and Bartonek JC. 1970. Bias associated with food analysis in gizzards of blue-winged teal. J. Wildl. Manage. 34:739-746.

Thompson JK. 1998. Trophic effects of *Potamocorbula amurensis* in San Francisco Bay, California. Proceedings of the Eighth International Zebra Mussel and Aquatic Nuisance Species Conference, Sacramento, California.

Tillman T, Edward G, and Urquhart K. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates in Montezuma Slough, August-October 1993. Department of Fish and Game, Bay-Delta and Special Water Projects Division, Stockton, CA. 25 p.

Unger PA. 1994. Quantifying salinity habitat of estuarine species. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. IEP Newsletter Autumn 1994:7-10.

[USACE] U.S. Army Corps of Engineers. 1979. Permit No. 12572-58. San Francisco District, Regulatory Functions Branch.

_________. 1986. Permit No. 16223E58. San Francisco District, Regulatory Functions Branch.

[USBR *et al*] U.S. Bureau of Reclamation, California Department of Water Resources, California Department of Fish and Game, and Suisun Resource Conservation District. 1987. Suisun Marsh Preservation Agreement. March 2, 1987.

[USDA] U.S. Department of Agriculture, Soil Conservation Service. 1977. Soil Survey of Solano County, California. Pp. 76-79.

[USEPA] U.S. Environmental Protection Agency. 1993. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. 521 pps.

[USFWS] U.S. Fish and Wildlife Service. 1981. Section 7 Determination, Suisun Marsh Management Study. Sacramento Endangered Species Office. December 7, 1981.

__________. 1984. Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan. USFWS, Portland, Oregon. 141 pp.

__________. 1987. Standard Operating Procedures for Aerial Survey of Waterfowl and Habitats on the Breeding Grounds in North America. Co-op U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 95 pp.

__________. 1992. Measures to improve the protection of chinook salmon in the Sacramento/San Joaquin River Delta. Expert testimony for State Water Resources Control Board Water Right Phase of the Bay/Delta Estuary Proceedings. WRINT-USFWS-7. 84 p.

__________. 1994. Abundance and survival of juvenile chinook salmon in the Sacramento-San Joaquin Estuary. 1993 Annual Progress Report. FY 93 Work Guidance. Stockton (CA): U.S. Fish and Wildlife Service. 81 p.

[USGS] U.S. Geological Survey. 1997. Field Methods for Vegetation Mapping. (complete document available at the following website: http//:biology.usgs.gov/npsveg/fieldmethods.html).

[USGS *et al*] U.S. Geological Survey, Suisun Resource Conservation District, California Department of Water Resources, University of California at Davis, Ducks Unlimited, California Waterfowl Association. 1999a. Use of red-colored ponds by waterfowl wintering in the Suisun Marsh, CA. Suisun Resource Conservation District, Susiun, CA. 15 pp.

_________. 1999b. Suisun Marsh Red Water Study, Part 2 – Captive Bird Study. Suisun Resource Conservation District, Suisun, CA 24 pp.

Vayder J. September 14, 1989 memo to Walter G. Pettit, Chief of the Division of Water Rights, SWRCB titled “Effectiveness of the Suisun Marsh Salinity Control Gates”. From Chief of Central District, California Department of Water Resources. Located at Environmental Services Office, Sacramento CA.

Vigg S, Poe TP, Predergast LA, Hansel HC. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Trans Am Fish Soc 120:421-438.

Wang JCS. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary Technical Report 9. Sacramento (CA): California Department of Water Resources.

Wernette F. 1987. Plan to Manage 1,000 Acres of DFG Lands in the Suisun Marsh for the Salt Marsh Harvest Mouse. Interagency Memorandum, June 19, 1987. Department of Fish and Game, Bay Delta and Special Water Projects Division, Stockton.

[WESCO] Western Ecological Services Company. 1986. A review of the population status of the Suisun shrew (Sorex ornatus sinuosis) Final report. Prepared for U.S Fish and Wildlife Service, Sacramento CA. FWS 8502. 59pp + appendix.

Zar JH. 1999. Biostatistical Analysis. Prentice Hall. pp. 228-229.

SUISUN MARSH MONITORING AGREEMENT
Among
The Department of Water Resources
The Department of Fish and Game
and
The United States Bureau of Reclamation

March 2, 1987

SYNOPSIS OF THE SUISUN MARSH MONITORING AGREEMENT

Parties: The California Department of Water Resources, the California Department of Fish and Game, and the United States Bureau of Reclamation.

Type: Monitoring Agreement

Date: March 2, 1987

Agreement No. B-56322

Objective: To establish the methodology and carry out an appropriate monitoring program to meet the objectives of the Suisun Marsh Preservation Agreement.

Plan: DWR will perform water and soil salinity monitoring and DFG will perform vegetative monitoring in the Suisun Marsh. Studies will be conducted as necessary to determine the impacts on fish habitat associated with the Suisun Marsh Salinity Control Gates and surveys of the population of salt marsh harvest mouse. DFG will be reimbursed for the cost of vegetative monitoring and necessary special studies.

Cost: Total cost unknown

Cost Sharing: USBR (on behalf of the CVP) will pay forty percent (40%) and DWR (on behalf of the SWP) will pay forty percent (40%) of the costs incurred by DWR to implement Articles 3, 4(b), 5(b), and 6 of the Agreement. The remaining twenty percent (20%) will be from funds appropriated by the Legislature to finance a portion of the mitigation responsibility of other upstream diverters.

Review: Every five years, the program will be reviewed to see if it can be improved or reduced. Monitoring on Individual Ownerships will be terminated on September 30, 1990, unless the parties mutually agree otherwise.

Term: Until terminated by the written agreement of all parties.

TABLE OF CONTENTS

SUISUN MARSH MONITORING AGREEMENT
Among
The Department of Water Resources
The Department *of* Fish and Game
and
The United States Bureau of Reclamation

THIS Agreement dated this 2nd day of March, 1987, is hereby entered into among the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) and the United States Bureau of Reclamation (USBR) to provide for the implementation of the monitoring program of the Plan of Protection (Plan) for the Suisun Marsh (Marsh).

AGREEMENT

1. Definitions - When used herein, the term:

(a) "Control Station" (Station) shall mean a location listed in Table II of the Suisun Marsh Preservation Agreement

(b) "Electrical Conductivity" (EC) shall mean the electrical conductivity of a water sample measured in millimhos per centimeter (mmhos/cm) corrected to a standard temperature of 25 Celsius determined in accordance with procedures set forth in the publication entitled, "Standard Methods of Examination of Water and Waste Water,[1]" published jointly by the American public Health Association, the American Water Works Association, and the Water Pollution Control Federation, 13th Edition, 1971, including such revisions thereof as may be made subsequent to the date of this Agreement which are approved in writing by the parties.

(c) "Suisun Marsh Preservation Agreement" shall mean that agreement dated March 2, 1987, among DWR, DFG, the Suisun Resource Conservation District (SRCD), and the USBR detailing the construction and operation and responsibilities for the Plan of Protection.

(d) "Individual Ownership" shall mean separately owned parcels of land in the Marsh, other than those on Roe, Ryer, Freeman, and Snag Islands. Contiguous parcels owned by the same legal entity comprise a single Individual ownership.

(e) "Monitored ownership" shall mean those Individual ownerships with SRCD ownership numbers 406, 416, 422, 501, 504, 513, 702, 714, 804, and 905, plus the eastern portion of the Grizzly Island Wildlife Area and the Joice Island Wildlife Area.

(f) "Plan of Protection" (Plan) shall mean the plan prepared by DWR, dated February 1984, to mitigate the effects of the State Water Project (SWP) and the Central Valley Project (CVP) upon the Suisun Marsh.

2. Objectives

The objectives of this Agreement are to describe a methodology and define the scope of DWR's, USBR's and DFG's obligations to carry out an appropriate monitoring program to meet the objectives of the Suisun Marsh Preservation Agreement.

3. Monitoring

(a) The following water monitoring will be done:

(i) Channel Water Quality (EC)

The EC at the Control Stations will be monitored by DWR with continuous recorders. When the facilities constructed pursuant to subarticle (a) of Article 8 of the Suisun Marsh Preservation Agreement Become Operational, SC data from a location in the western Marsh will be telemetrically reported. If additional facilities are constructed, additional stations will be telemetered if necessary to assure compliance with the applicable water quality standards in Article S of the Suisun Marsh Preservation Agreement.

(ii) Diversion and Drain Water Quality

A point on each Monitored Ownership shall be monitored continuously for EC by DWR.

(iii) Standing Surface Water

The EC of standing surface water at each soil water salinity sampling site identified in subarticle (a)(v) shall be determined monthly by DWR.

(iv) Water Level

DWR *shall maintain a continuous recorder to* measure water elevation on each of the Monitored Ownerships. At each of the Control Stations DWR shall maintain a continuous recorder to measure water elevation for five years.

(v) Soil Water Salinity

Soil water salinity will be monitored by DWR at 40 to 50 sites on Monitored ownerships and one site on Individual ownership 423. Soil water salinities will be measured monthly following the methodology described in Appendix B o+ the Plan which is made a part of this Agreement.

(b) The following vegetative monitoring will be done using. the methodologies described in the Plan:

(i) Plant Survey

The species composition of vegetation on lands within 35 meters of each soil water monitoring site will be determined by DFG in August or September of each year. The percent of cover contributed by each plant species present on the sample site will be determined by DFG each year.

(ii) Seed Production

The seed production of alkali bulrush and fat hen present on lands within 35 meters of each soil water monitoring site will be determined by DFG each year.

(iii) Marsh-Wide Plant Survey

The overall vegetative composition of the Marsh shall be determined by DFG every third year beginning in 1985 utilizing color aerial photography in conjunction with ground verification. DWR shall obtain and DFG shall analyze the aerial photographs. These aerial photos will also be used by DFG to determine any net acreage changes in preferred salt marsh harvest mouse habitat in compliance with the Section 7 Determination, Suisun Marsh Management Study by the U. S. Fish and Wildlife Service dated December 7, 1981.

4. Wildlife

(a) Species and number of waterfowl in the Marsh will be determined from aerial surveys carried out by DFG from September through January of each year at DFG expense.

(b) If the marsh-wide plant survey (Article 3(b)(iii)) indicates a significant change, as identified in the Section 7 Determination, in preferred habitat within the Marsh for the salt marsh harvest mouse, then the parties shall determine whether any surveys of the population of the mouse are necessary. If such surveys are necessary, then DWR will promptly arrange for such surveys to be made.

5. Fish Habitat

(a) DWR or DFG will arrange for or conduct studies of the annual abundance of young striped bass and Neomysis in Montezuma Slough.

(b) DWR will contract with DFG or, in consultation with DFG, contract with other knowledgeable experts to conduct studies to determine the impact of predators and disruption of fish associated with the Montezuma Slough Control Structure. The need for additional fishery monitoring will be evaluated as each subsequent unit becomes operational.

6. Reports

(a) All reports and data compiled under this Agreement shall be promptly distributed to the parties and SRCD. Preliminary data and the report described below will be made available by DWR to interested parties upon request as soon as possible following collection and completion, respectively.

(b) A monthly summary of EC data from the Control Stations will be provided by DWR to the other parties and SRCD. Weekly or daily data will be provided in response to specific requests by the parties or SRCD.

(c) A report of data for each water year will be produced jointly by DWR and DFG which will include.- (1) a summary of the channel, diversion, drain, soil water salinity and water level measurements; the plant survey and production measurements; the waterfowl population surveys, (2) every third year the status of the overall vegetative composition of the Marsh, (3) results of any surveys made of salt marsh harvest mouse popu4ations, (4) comparisons of soil water, applied water, and channel water salinities, and plant production to demonstrate the effectiveness of the plan and identify areas where additional action is needed, (5) results of other studies as they become available, and (6) conclusions and recommendations on modification of the monitoring program to achieve its objectives. This report will be completed by April 1 of each year, or four months after a summary of the water monitoring data is available, whichever is later.

7. Costs

(a) USBR shall pay Forty Percent (40%) and DWR shall pay Sixty Percent (60%) of the costs incurred to implement Articles 3, 4(b), 5(b), and 6.

(b) The Fish Habitat studies identified in Article 5(a) shall be funded through the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, and not through funds provided herein.

(c) Funding for monitoring on Individual Ownerships as provided in Subarticles 3(a)(ii) through 3(a)(v), 3(b)(i), and 3(b)(ii) shall terminate on September 30, 1990.

(d) The term "costs" shall include all administrative overhead, costs of liability insurance or pooling programs and other costs similar to those normally incurred by USBR which are incurred by DWR in performance of this Agreement.

(e) The United States shall pay to DWR the costs determined to be allowable by the Contracting Officer in accordance with the terms of this Agreement and with provisions of Federal Acquisition Regulations (FAR), Part 31, Subpart 6, 48 CFR Sections 31.601-31.603. If DWR uses any funds advanced pursuant to this Agreement for purposes not in accordance with this Agreement or not in compliance with FAR Part 31, Subpart 6, DWR shall reimburse USBR for the amount of any such improperly used funds.

(i) The USBR's share of costs incurred by DWR prior to the date of this Agreement but after January 1, 1979 plus the interest from the dates such costs were incurred, at the State Surplus Money Investment Fund rates, shall be paid in a lump sum payment following an audit of such costs by an authorized representative of the USBR, to be completed within six months after execution of this Agreement.

(ii) On or before the first day of each month, after the date of this Agreement, USBR shall advance its contributions specified in this Article, in accordance with a billing statement furnished by DWR regarding expenditures estimated to be incurred during the upcoming month. Adjustments for overpayments or underpayments during a quarter shall be made in the quarter immediately following. Advances will be maintained at a level commensurate with current needs.

(f) Each year on or before September 15, DWR shall furnish to USBR a proposed budget of the estimated costs by quarter to be incurred under Articles 3, 4(b), 5(b), and 6 of this Agreement during the fiscal year beginning a year later on October 1, and the respective contributions of the parties. USBR shall notify DWR by the following September 15 of its full or partial approval of DWR's proposed budget. USBR's approval shall not be unreasonably withheld. In the event that USBR does not approve all budgeted costs, such unapproved costs shall not be eligible for reimbursement by USBR until such time as they are mutually agreed upon by DWR and USBR. To facilitate USBR's review, each year's proposed budget should include a schedule of estimated costs by each monitoring requirement identified in Articles 3, 4(b), 5(b), and 6, or by descriptive title, supplemented with a narrative description which adequately describes and explains all major aspects of the fiscal year's proposed program.

(g) Separate cost accounts shall be maintained by physical feature or descriptive title to permit ready audit.

8. Miscellaneous Provisions

(a) By October 1 of each year, UFO shall submit a budget to USBR and DWR for approval of the work for which DFG is to be reimbursed. The parties may mutually agree to have the work done by someone other than DFG.

(b) DWR agrees to pay DFG the cost of performance hereunder and to pay actual expenses as often as monthly in arrears.

(c) The expenditure of any money and the performance of any work by the United States hereunder which may require appropriation of money by the Congress or the allotment of funds shall be contingent upon such appropriation or allotment being made. No liability shall accrue to the United States in case such funds are not appropriated or allotted.

(d) DWR will make all reasonable attempts to maintain full and complete records at all monitored sites provided for by this Agreement. DWR will be excused from monitoring at a site at times when monitoring is impeded by temporary equipment breakdowns, physical conditions, or lack of right of access. However, DWR shall immediately notify DFG of these occurrences. DWR shall make all reasonable efforts to expeditiously replace faulty equipment and reestablish monitoring.

(e) Unless otherwise expressly provided, all management and operational decisions necessary to implement this Agreement shall be by mutual agreement of the parties.

9. Review

During the year following each fifth year of data collection, or at other times when requested by one of the parties to this Agreement, the parties will review the Agreement and identify any modifications appropriate for accomplishing its objectives. Any modifications shall be made by amending this Agreement and implementation of such modifications shall be subject to any necessary approvals by control agencies. It is the intent of the parties to reduce the *scope* of the monitoring program, particularly monitoring on Individual Ownerships, as soon as sufficient information is available to confirm the salinity relationships. The monitoring on Individual Ownerships shall terminate on September 30, 1990-unless the parties mutually agree otherwise.

10. Term of Agreement

This Agreement and any amendments hereto shall continue in full force and effect until terminated by the written agreement of the parties. SRCD shall be notified prior to any such termination.

11. Amendments

This Agreement may be amended by mutual agreement of DWR, DFG, and USBR. SRCD shall be notified of any proposed amendments.

12. Notices

All notices that are required either expressly or by implication to be given by one party to another shall be deemed to be given if delivered personally, or if enclosed in a properly addressed postage prepaid envelope with return requested and deposited in a United States Post Office. Unless or until formally notified otherwise, the parties shall be addressed as follows:

Director, Department of Water Resources
P.O. Box 388
Sacramento, CA 95802

Director, Department of Fish and Game
1416 - Ninth Street
Sacramento, CA 95814

U.S. Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95825

SUISUN MARSH
MONITORING PROGRAM METHODOLOGY

The methodology to carry out the monitoring program described in Chapter 7 is described below. It is divided into water quality, soil salinity, vegetation and fisheries elements.

Water Quality

I. Channel Water Quality. As required by State Water Resources Control Board (SWRCB) Decision 1485, six sites in the Marsh and two sites on the Sacramento River (Chipps Island or its equivalent and Collinsville) will continue to be monitored for EC by the Department of Water Resources (DWR). These sites are instrumented with Martek Electrical Conductivity Sensors and Recorders. An additional site known as D-7 (Grizzly Bay) has been and will continue to be periodically monitored by the DWR.

In addition to the required sites, DWR will install EC sensors and recorders at three new sites on tidal sloughs to provide additional channel water quality data. The monitoring sites are shown on Figure 32. Fisher-Porter EC sensors with punch papertape recorders, which have proven to be effective with a minimum of maintenance and breakdown will be used. These instruments are battery operated and the data tapes can be readily reduced through computerized operations.

The mean and range of high tide EC's should be recorded at each station monthly and reported to the Suisun Marsh Technical Committee (SMTC) and SWRCB prior to the last day of the succeeding month. A monthly grab sample near the mouth of Montezuma Slough will be collected beginning October 1, 1984.

II. Diversion and Drain Water Quality. Utilizing the Fisher-Porter EC instruments previously described, data will be obtained on a continuous basis at a point on each individual ownership being monitored for soil water salinity. The recorder will be placed at locations determined to be compatible with the specific sites to be monitored for soil water salinity. These locations generally will be at the major inlet, including but not limited to on-ownership project diversion points, of each marsh management unit[1/] being monitored. Field data shall be collected monthly and the mean monthly salinity and range of salinities reported to the SMTC as soon as possible.

1/ A Marsh management unit is comprised of a single individual ownership or a series of fields on a State Wildlife Area with common drainage facilities.

The EC of standing surface water at each soil water sampling site shall be determined monthly and shall be reported to the SMTC as soon as possible.

III. Water Level Recorders. Water level recorders (continuous stage) will be installed on all individual ownerships being monitored for soil salinity. These recorders will show how each individual ownership's water is managed, when the drain and flood cycles occur, and for what time duration. Data will be collected monthly and the mean and range of depths reported to the SMTC as soon as possible.

Soil Water Salinity

I. Soil Water Salinity. Soil water salinity will be monitored in the first foot of soil, utilizing soil water extractors installed in triplicate 6 inches below the soil surface at approximately 50 sites on 12 individual ownerships selected to cover major variations in management practices, vegetation, and soil types which will be determined on the basis of the U. S. Soil Conservation Service (SCS) criteria. The EC of the soil water will be a direct reading. The specific sites to be monitored within each individual ownership shown on Figure 32 were determined during program implementation and selected with the assistance of a Department of Fish and Game (DFG) representative knowledgeable about the Marsh.

The western, central, and eastern Marsh are all represented. Sites have been chosen that vary in management practices and cover the five major soil types: Joice, Reyes, Tamba, Suisun, and Valdez. Likewise, several of the major vegetation types were covered. Samples are located in sites dominated by either alkali bulrush, pickleweed, fat-hen, or brass buttons. Sites with complex vegetative matrices of each of these species were also sampled.

The Marsh management units to be monitored shall be: individual ownership's numbers 406, 416, 426, 501, 504, 520, 513 (tidal), 702, 804, and 905, the eastern portion of the Grizzly Island Wildlife Area and the Joice Island Wildlife Area as shown on Figure 32. Monitoring locations may be altered by consensus of SMTC, SWRCB, and the San Francisco Bay Conservation and Development Commission (BCDC).

The mean EC of water in the first foot of soil will be determined monthly at each extractor provided that sufficient soil moisture exists to obtain an adequate sample. The mean EC of soil water in the first, second, and third foot of the extractor site monitoring fat-hen will be determined each month. When the soil moisture level approaches or passes the wilting point, usually mid to late summer, it may not be possible to obtain a soil water sample. When this happens soil samples shall be collected and processed gravimetrically. Results shall be reported to SMTC as soon as possible.

Soil water is drawn into and from the soil water extractor by applying a vacuum to tubes extending from the instrument. The EC of extracted samples will be measured, using standard procedures with the data recorded in millimhos. The EC data will be converted to TDS and chlorides using relationships determined through laboratory analysis. Field analysis of the samples will also include determining the pH value.

The accuracy of determining the average EC of the first foot of soil using a single extractor at the 6-inch level will be tested. The results of monitoring with soil salinity extractors located at 6 inches will be compared to the results from extractors placed at 3 and 9 inches in addition to the 6-inch depth on Reyes and Joice Series soils at locations of both high and low surface water salinity. Sampling sites will be located on the eastern portion of the Grizzly Island Wildlife Area and on the Morrow Island Land Company (Individual Ownership 702) lands. Samples will be taken monthly from each extractor for one full year.

Since salinity tolerances of important marsh plants were reported gravimetrically by Mall in 1969 and formed the basis upon which the Decision 1485 water quality standards were developed, it will be necessary to determine the relationship between soil EC obtained gravimetrically and that obtained with the soil water extractors.

To accomplish this, soil samples will be collected adjacent to the selected tri-level soil water extractors. There will be two sampling sites, one for each soil type. Soil samples will be collected monthly at 0 to 6-inch and 6 to 12-inch depths. A total of 144 soil samples will be collected (2 soil types times 3 extractors times 2 soil samples, at 0-6 inches and 6-12 inches, times 12 months). These samples should be collected concurrent with the normal sampling activities for one year beginning with the installation of the monitoring instrumentation.

The extraction of soil samples near the buried soil water extractors has a potential for providing tubes for piping of surface water and affecting the EC water sampling tubes and the EC sensor blocks. These core holes need to be carefully selected and should be a given distance from the soil water extractors, such as 3 feet. The holes made by the core should be filled, with foreign soil, or closed by stomping in and around the core hole. Otherwise there may be some potential for erroneous results.

The SWRCB and/or DFG shall conduct the statistical analysis necessary to determine the relationship between the two sampling procedures. The SWRCB and DFG shall conclude their analysis and shall report their findings to SMTC within three calendar months following their receipt of one full year of sampling data. The sampling methodology shall be reevaluated at that time.

Vegetation

Vegetative sampling is an important segment of the overall monitoring program for the Plan of Protection. This program was carefully designed and approved by the Suisun Marsh Technical Committee (SMTC) to meet the monitoring requirements set forth in the State Water Resources Control Board's Decision 1485 (D-1485). The program not only monitors channel water salinity for compliance with D-1485 but also provides a mechanism for determining the resulting soil water salinities produced on individual ownerships. Soil water salinity and length of submergence are the two most important factors governing vegetative composition in the Suisun Marsh (Mall 1969, Pearcy, et al. 1982).

I. Plant Survey. The composition of the vegetation immediately adjacent to each soil water monitoring site will be determined by DFG in August of each year. The percent of cover contributed by each plant species present on the sample site will be determined by a method which will not result in invalidating the site in future years. Such method shall be acceptable to the members of the SMTC, BCDC, and SWRCB.

II. Seed Production. The seed production of alkali bulrush present immediately adjacent to each soil water monitoring site will be determined in August of each year. Seed yield will be measured by clipping the seed heads from all plants contained within a square-meter plot. The weights of cleaned seed from each plot will be reported in pounds per acre. The results shall be reported by DFG, to SMTC, BCDC, and SWRCB prior to the end of the calendar year.

The seed production of fat-hen plants adjacent to the soil water monitoring sites on the fat hen monitoring unit shall be determined each year. The time of sampling has yet to be determined but will probably be in September. Results shall be provided by DFG, to SWRCB, BCDC, and SMTC no later than December 1.

The overall vegetative composition of the Suisun Marsh shall be determined every third year utilizing color aerial photography in conjunction with ground verification. The results of these surveys will be compared to the results from past flights and will be reported in acres and percent of total vegetation for each major plant species. The DWR will be responsible for providing the color aerial photographs, and the DFG will complete the analysis. The DFG shall report the results to the SMTC, BCDC, and SWRCB within 6 months after receipt of the completed photo survey.

The Marsh-wide aerial photo survey will also be used to monitor the extent of preferred salt marsh harvest mouse habitat. This monitoring is a requirement of the U. S. Fish and Wildlife Service's Section 7 determination (Appendix E). The biological assessment in Appendix D (pages 47 to 49) describes the methodology for this monitoring.

Wildlife

Present biweekly aerial waterfowl surveys will be continued and will be carried out from September through January of each year. Contracts will be let with DFG or other knowledgeable wildlife experts to make surveys of the populations of the black and clapper rails, and the saltmarsh harvest mouse within the Marsh.

The results will include the numbers and distribution of each species under study and will be reported to SMTC, BCDC, and SWRCB within one month from the end of the year in which the studies are made.

Fisheries

1. Fish Screen Testing. DWR and DFG have evaluated the effectiveness of the test screen at the Roaring River Slough intake. The test results show that the fish screen at the Roaring River Slough Intake are required. This evaluation provided the basis for the design of more screens for this diversion structure. The second stage installation of fish screens is to be completed by October 1983. Fish occurrence studies will be made after construction of the Morrow Island and Grizzly Island Distribution Systems intakes. Fish screens will be constructed at these intakes if the occurrence studies show a need for them.

2. Fisheries Habitat. DWR will contract with DFG or other knowledgeable experts to study: (a) the fish occurrence and distribution in the marsh channels after completion of the Overall Facilities; (b) impact of predators and disruption of fish associated with the Montezuma Slough control structure; (c) impact of tidal pumping on migratory fish. DWR will continue its support of and participation with the 4-Agency study program including the summer tow net survey, the fall midwater trawl survey, and the Neomysis study. Fisheries evaluation will be coordinated through the 4-Agency study program.

Reports

Preliminary data will be submitted to the SMTC as soon as possible following collection of the data. The preliminary data collected by DWR to be submitted for each month will be the highs, lows, and means of the EC of the channel water, pond water,

water diverted to the clubs being monitored, any drainage water monitored: the continuous stage records, and the soil EC both gravimetrically and by direct readings (extractor values). The results of the fisheries surveys will be reported as soon as possible after completion of the work.

An annual report will be produced which will include: (1) the data obtained from each of the parameters discussed above; and (2) comparisons of soil and channel water salinities and plant production to demonstrate the effectiveness of the program and identify areas where additional action is needed.

Program Implementation

Upon approval of the program, permits will be obtained for each site and needed personnel will be recruited. Site selection, instrument installation, and data collection will commence as soon as equipment has been obtained. The program will be implemented on a phased basis beginning upon program approval and will be fully implemented within 2 years.